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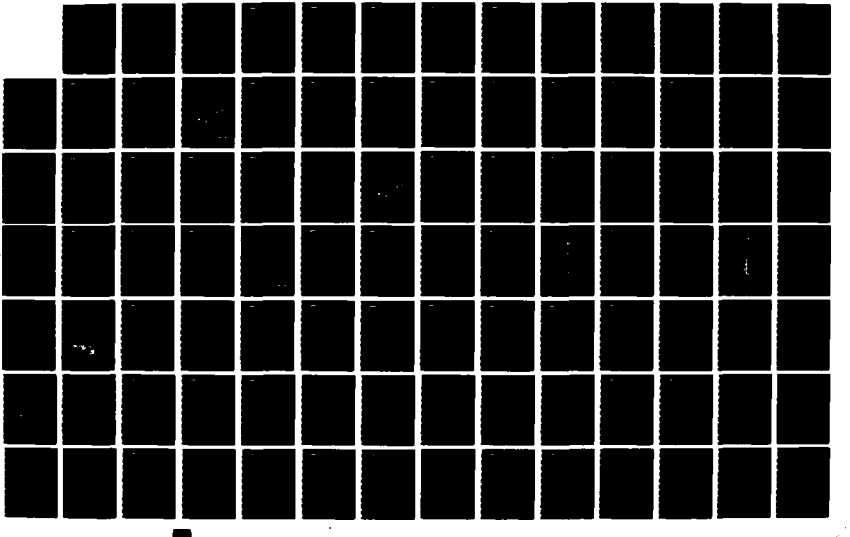

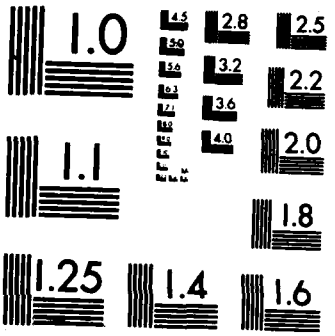

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INSTALLATION RESTORATION PROGRAM
PHASE II - CONFIRMATION/QUANTIFICATION
STAGE 1

VOLUME 1

FINAL REPORT FOR
CARSWELL AFB, TEXAS

HEADQUARTERS STRATEGIC AIR COMMAND
COMMAND SURGEON'S OFFICE (HQSAC/SGPB)
OFFUTT AFB, NEBRASKA 68113

OCTOBER 1986

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The purpose of the Phase II Stage 1 investigation was to determine if environmental contamination has resulted from waste disposal practices at Carswell AFB. In addition, the investigation included an estimate of the magnitude and extent of contamination, identification of environmental consequences of migrating pollutants, and recommendation of additional investigations to identify the magnitude, extent and direction of movement of discovered contaminants. Phase II (Stage 1) work at Carswell AFB focused on eleven sites and the Weapons Storage Area west of the base. These sites are located in two main areas: near the Flightline, and near the main gate.

A geophysical and hydrogeological investigation was conducted at several landfills, fire training areas, and fuels handling areas to determine if environmental contamination has resulted from waste disposal and materials handling operations at Carswell AFB. Magnetometer, electromagnetic profiling, and earth resistivity surveys were conducted at several locations. Ground-water monitor wells were installed in alluvial materials and the Paluxy aquifer. Soil samples were collected at selected sites and analyzed for a broad range of parameters. Water samples collected from the wells and streams were analyzed for metals, organic indicator parameters, and purgeable organics.

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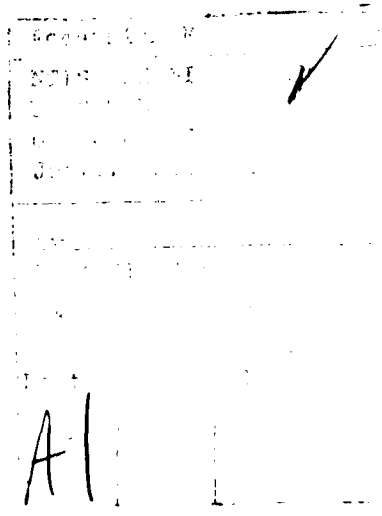

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TABLE OF CONTENTS
(Volume 1)

RADIAN CORPORATION

TABLE OF CONTENTS (Continued)

RADIAN CORPORATION

TABLE OF CONTENTS

(Volumes 2 and 3)

RADIAN CORPORATION

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

RADIAN CORPORATION

List of Tables

RADIAN CORPORATION

LIST OF TABLES (Continued)

RADIAN CORPORATION

LIST OF TABLES (Continued)

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PREFACE

Radian Corporation is the contractor for the Installation Restoration Program (IRP) Phase II, Stage 1 investigation at Carswell AFB, Texas. The work was performed under USAF Contract No. F33615-84-D-4402, Delivery Order 0006.

A geophysical and hydrogeological investigation has been conducted at several landfills, fire training areas, and fuels handling areas to determine if environmental contamination has resulted from waste disposal and materials handling operations at Carswell AFB. Magnetometer, electromagnetic profiling, and earth resistivity surveys were conducted at several locations. Ground-water monitor wells were also installed in alluvial materials and the Paluxy aquifer. Soil samples were collected during drilling operations at wells and with hand augers at selected sites and analyzed for a broad range of parameters. Water samples collected from the wells and streams were analyzed for metals, organic indicator parameters, and purgeable organics.

Key Radian project personnel were:

Marshall F. Conover - Contract Administrator
Thomas W. Grimshaw - Program Manager
Lawrence M. French - Project Director and Supervising Geologist
Jenny B. Chapman - Supervising Geologist.

Radian would like to acknowledge the cooperation of the Carswell AFB Bioenvironmental Engineering and Civil Engineering Staffs. In particular, Radian acknowledges the assistance of Capt. Ravid R. Carpenter, Chief Bioenvironmental Engineer, and Lt. David Parker.

The work reported herein was accomplished between December 1984 and April 1985. Major George R. New, Technical Services Division, USAF Occupational Environmental Health Laboratory, was the Technical Monitor.

SUMMARY

Background and Purpose

The Department of Defense (DOD) is conducting a nation-wide program to evaluate waste disposal practices on DOD property, to control the migration of hazardous contaminants, and to control hazards that may result from these waste disposal practices. This program, the Installation Restoration Program (IRP), consists of four phases: Phase I, Initial Assessment/Records Search; Phase II, Problem Confirmation/Quantification; Phase III, Technology Base Development; and Phase IV, Remedial. The United States Air Force (USAF) has initiated an IRP investigation at Carswell Air Force Base near Fort Worth, Texas.

Phase I studies for the Carswell AFB Installation Restoration Program were completed in February 1984. The purpose of the Phase I study was to conduct a records search for the identification of past waste disposal activities which may have caused ground-water contamination and the migration of contaminants off-base.

Twenty-two disposal or spill sites, seventeen sites at Carswell AFB and five sites at the Weapons Storage Area located west of Carswell AFB, were identified as possibly containing hazardous waste. The potential for adverse environmental consequences of each site was evaluated with a rating or scoring system. This system took into account such factors as the site environmental setting, the nature of the wastes present, past waste disposal practices and the potential for contaminant migration. Ten sites were not considered to present significant concern for adverse effects on health or the environment.

Twelve sites of the twenty-two Phase I sites were selected for Phase II Stage 1 studies. Radian Corporation performed the Phase II Stage 1 Field Evaluation under USAF Contract No. F33615-84-D-4402, Delivery Order 0006.

The purpose of the Phase II Stage 1 investigation was to determine if environmental contamination has resulted from waste disposal practices at Carswell AFB. In addition, the purpose of the investigation included an estimate of the magnitude and extent of contamination, the identification of environmental consequences of migrating pollutants, and the recommendation of additional investigations to identify the magnitude, extent and direction of movement of discovered contaminants.

Authorization to proceed on the Carswell AFB Phase II Stage 1 program was given on 29 September 1984. Field activities were started during December 1984 after an initial site visit on 21 November 1984 and after field safety and sampling plans were developed. The field work consisted of geophysical surveys, coring and sampling of near-surface soil at several locations, installation of upper zone and Paluxy ground-water monitor wells, sampling of surface water, and sampling of ground water from completed wells and borings.

Location and Site Descriptions

Phase II (Stage 1) work at Carswell AFB has focused on eleven sites shown on Figure 1 and the Weapons Storage Area west of the base. These sites consist of landfills, fire training areas, industrial areas, and spill sites that were located in two main areas. One group of sites is near the Flightline and another set of sites is concentrated near the main gate.

Site 1, Landfill 1

Landfill 1 was reported to be the original base landfill and was operated during the 1940s. This site is located adjacent to the Trinity River levee at the same spot as the current Defense Reutilization and Marketing Office (DRMO) storage yard. Due to the time elapsed since this site was closed, no information was available concerning past waste disposal practices at this location.

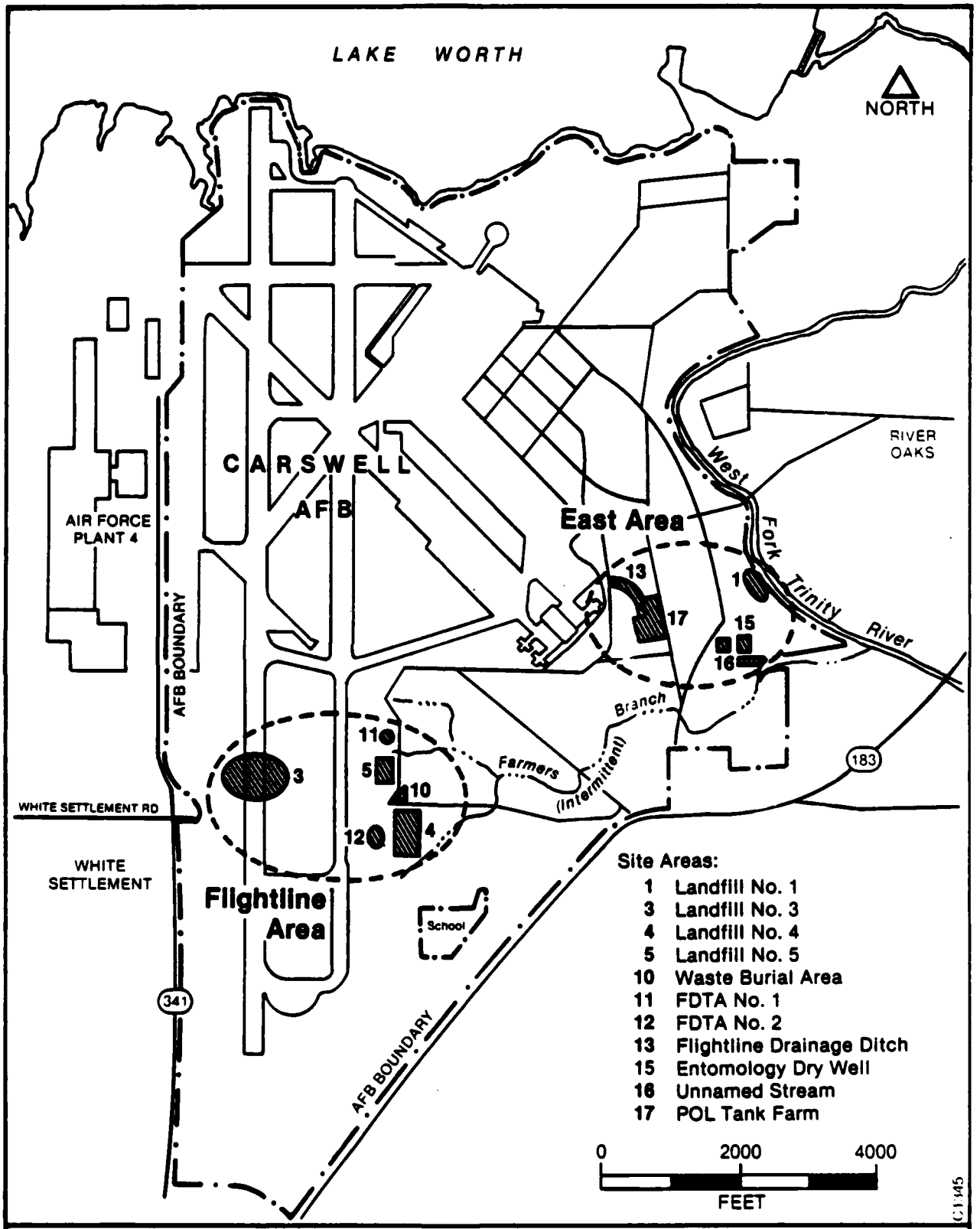

Figure 1. Location of Phase II Stage 1 Sites, Carswell AFB, Texas.

Site 3, Landfill 3

Landfill 3 is located under the present runway, immediately south of the culvert carrying the flow of Farmers Branch. During the period from 1950 until 1952, Site 3 was used for burial of all types of wastes, but primarily construction rubble. During that period, the runway ended north of Farmers Branch, and a ravine present at this site was used as a fill area.

Site 4, Landfill 4

Landfill 4 includes 10 acres of land east of the runway and was the main landfill during much of the history of Carswell AFB. At least six large pits, approximately 12 feet deep were filled with refuse which was burned and buried. Various materials suspected of being hazardous were reportedly disposed at this site, including drums of waste liquids, partially full paint cans, and cadmium batteries.

Site 5, Landfill 5

Landfill 5 is located northwest of Landfill 4 and was constructed adjacent to a small tributary to Farmers Branch. The landfill site was constructed by building a clay berm adjacent to the creek and then filling the area behind the berm up to its existing level. This fill site received all types of flightline wastes and refuse, and was regularly burned prior to covering.

Site 10, Waste Burial Area

Site 10, located adjacent to and north of White Settlement Road, where it dead-ends at the taxiway, was used for burial of wastes during the 1960s. Various types of hazardous materials, including drums of cleaning solvents, leaded sludge, and possibly ordnance materials, were reported disposed of at this site.

Site 11, Fire Department Training Area 1

Site 11, north of Landfill 5, was the primary fire pit prior to 1963. The pit reportedly was adjacent to a small tributary to Farmers Branch, was gravel-lined, and had a low concrete curb around its perimeter. Waste oils and contaminated fuels were the primary flammable liquids used in the exercises.

Site 12, Fire Department Training Area 2

Site 12 is located between the north-south taxiway and the radar facility. This site, with only slight modifications, has been used as a fire department training area since 1963. The fire ring is gravel-lined with a low earthen berm around its perimeter. In the past, a pit was present at the site to collect runoff from training exercised, but this pit has been filled.

Site 13, Flightline Drainage Ditch

Site 13 is an unlined drainage ditch from Haile Drive to where it intersects the POL tank farm, at which point it enters a concrete-lined channel. In addition to normal storm drainage, this ditch receives discharges from the aircraft washracks and the Fuel Systems Shop (Building 1048). Washrack wastes (PD-680, a cleaning solvent, and soap) can be discharged directly to the Facility 1190 oil/water separator, located adjacent to the flightline drainage ditch, or into the drainage ditch via an overflow pipe in the drain line between the washracks and the oil/water separator. Discharge to the oil/water separator or to the drainage ditch is controlled by a valve in the drain line just upstream of the separator.

Site 15, Entomology Dry Well

Site 15 is located immediately west of the old entomology shed (Building 1338), in the present Civil Engineering Compound, off Rogner Drive.

A dry well at the site was used for disposal of insecticide rinsate between 1965 and 1981. The site is currently vacant; Building 1338 has been demolished and the site has been regraded. Building 1338 was used for the storage and mixing of insecticides including malathion, diazinon, dursban, and chlordane, and for storage and cleaning of spray equipment. Chlordane has been reported in samples taken from the well next to Building 1338, although no documented analytical results could be found during the records search to substantiate this report.

Site 16, Unnamed Stream

Site 16 is a small tributary of Farmers Branch, located south of the old entomology shed, and near the confluence of Farmers Branch and the Trinity River. This small stream is the discharge from an oil/water separator located immediately south of the fenced civil engineering yard, and receives its perennial flow from ground water entering the separator. The separator is connected to a french underdrain system which was reportedly installed due to a gasoline leak at the former base gasoline station. This separator has not been routinely cleaned for a number of years and reportedly contained hydrocarbon constituents.

Site 17, POL Tank Farm

Site 17 is located on the eastern side of Carswell AFB, adjacent to Knight's Lake Road. In early 1985, three aboveground tanks were located at this location with a fourth under construction; formerly, three additional tanks were also located here. During the early 1960s, fuels were discovered in the ground in this area, and also downgradient from this site in the direction of the former base gasoline station. A french drain system was installed downgradient from this area to collect fuels in the ground. The french drain discharges through the oil/water separator at Site 16.

Weapons Storage Area (WSA)

The WSA is located about 11 miles west of Carswell AFB, just north of White Settlement Road. It has been reported that small quantities of waste cleaners and solvents have occasionally been disposed of on the ground behind the Inspection Shop.

Sampling and Analytical Program

The sampling program at Carswell AFB consisted of the collection of stream sediments, soils, surface water, and ground water. Stream sediments and surface water were collected as grab samples. Soil samples were collected with a hand-operated auger at some sites and with a hydraulic-powered split-spoon sampler during drilling activities. All soil samples were placed individually in glass jars and frozen. Ground-water samples were collected from the alluvial monitor well using a Teflon bailer. Permanently installed electric pumps were used to collect ground water from the Paluxy monitor wells and from the Weapon Storage Area well. All water samples were chilled to 4°C. Samples were shipped to Radian Analytical Services for analysis. The schedule of analyses is summarized on Table 1.

Field Program

The following paragraphs contain descriptions of the various field activities in the Carswell AFB Phase II Stage 1 investigation. The field program included geophysical surveys, hollow-stem auger and rotary drilling, monitor well installation, hand augering, and soil and water sampling.

Geophysical Surveys: Geophysical surveys were performed in order to accurately define the vertical and lateral extent of waste-disposal activities, provide a clearer picture of the subsurface conditions around the sites, and investigate the potential for buried objects at several locations. Several geophysical techniques were used during the investigations: earth

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TABLE 1. ANALYTICAL SCHEDULE FOR SOIL AND WATER SAMPLES, CARSWELL AFB, TEXAS

Parameter	Sites[1] 1	4	5	10	11	12	13	15	16	17	WSA
Total Organic Carbon	W	W	W	W	W	W		W	W	W	
Total Organic Halogen	W	W	W	W	W	W			W	W	
Oil and Grease	W,S	W	W,S	W,S	W,S	W,S	S		W,S	W,S	S
Lead									W,S		
EP Toxicity							S				
Pesticides	W,S	W	W,S		W,S			W,S			
Phenols	W,S	W,S	W,S		W,S	W,S					
Heavy Metals	W,S	W,S	W,S		W,S	W,S					
Purgeable Organics (Methods 601, 602)	W,S	W	W,S	W,S	W,S	W,S			W,S		S
COD		W	W								
Radiochemistry											W

[1] W = Water, S = Soil.

resistivity by direct current Schlumberger soundings (vertical electrical soundings - VES), magnetic and magnetic gradient surveying, and fixed frequency electromagnetic profiling (EMP) surveys at three different effective depths of exploration.

Drilling Techniques: Drilling at Carswell AFB was accomplished using a hollow-stem auger rig for the upper zone monitor wells and soil borings and a rotary drilling rig (using both mud and air) for the Paluxy monitor wells. These methods were selected on the basis of the anticipated depth of completion, need for water-level observations, and expected geologic conditions.

A hollow-stem auger drilling rig, the CME-75, was used to perform shallow soil borings and installation of the upper zone monitor wells. the hollow-stem method allowed for an accurate examination of soil conditions, identification of the position of the water table, and recovery of soil samples. The holes were drilled dry; no drilling fluids or additives were used. Samples of soil were collected with a split-spoon sampler at 5-foot intervals (ASTM D-1586). Selected samples were frozen and shipped to Radian's laboratory for chemical analysis. Upon reaching final depth, 2-inch diameter PVC monitor wells were installed at most sites.

The rotary drilling for Paluxy monitor wells was performed with a Gardner-Denver 1500 CD truck-mounted rig. A 6-inch bit was used to advance a pilot borehole through the upper zone and to at least 5 feet into the underlying Goodland Limestone. The borehole was then reamed to a diameter of 14 inches and a 10-inch diameter steel casing was installed. After grouting the annular spaces, the borehole was advanced using a 6-inch diameter bit to the final depth. A four-inch diameter PVC monitor well, with 40-foot screen and a dedicated submersible pump, was then installed in the borehole.

Ground Water Sampling: Samples of ground water were collected from eleven upper zone borings, twenty-three upper zone monitor wells, two Paluxy

wells, and a potable supply well. Most wells were sampled in two rounds during February and March, 1985.

Other Sampling: In addition to ground water sampling, several streams were sampled. Three locations at the Flightline area and two locations at the Unnamed Stream were sampled. Hand-augered borings were performed at several locations, particularly at the WSA and the Flightline Drainage Ditch (Site 13). Soil samples, as well as sediment samples, were collected for analysis at these locations.

Results of Analysis

The Phase II Stage 1 investigation has documented the presence of organic contamination, mostly trichloroethylene (TCE), in the upper zone soil and ground water at several sites. Concentrations of heavy metals were typically at background levels. No ground-water contaminantion was observed in the Paluxy aquifer. In addition, low levels of organic compounds were detected in small tributaries of Farmers Branch in the vicinity of several sites at the flightline. A summary of the analytical data for organic contaminants in upper zone ground water is provided in Table 2. Results of analyses of surface water are provided in Table 3, and results of soil analyses are given in Table 4.

Site 1: Ground water at Landfill 1 contains some elevated levels of oil and grease (ranging from not detected to 190 mg/L) and heavy metals, as well as some purgeable halocarbons in low concentrations. Ground water movement is toward the Trinity River, adjacent to the site.

Sites 4, 5, 10: Ground water in the vicinity of these sites was found to contain elevated levels of TCE. The occurrence of TCE was generally in the range of non-detectable to 5,000 ug/L in the affected areas both upgradient and downgradient of the landfills. Results of soil analyses also indicated TCE (range from none detected to 0.338 ug/g) contamination at some

TABLE 2. SUMMARY OF ORGANIC COMPOUNDS IN UPPER ZONE GROUND WATER, CARSWELL AFB, TEXAS

Parameter	Location								
	Site 1	Site 4	Site 5	Site 10	Site 11	Site 12	Site 15	Site 16	Site 17
ORGANIC INDICATORS (mg/L)									
Oil and Grease	<1-190	<1-23	<1-220	<1-310	<1-200	<1-69	<1-4	<1-7,100	<1-31,000
Phenols	0.005-0.074	<0.005-0.1	0.005-0.012	NA	0.005	0.005-0.021	NA	NA	NA
TOC	3-8	1-28	1-6	1-5	1-15	<1-5	NA	1-420	44-190
TOX	<0.01	NA	0.03-1.5	0.05-0.16	0.01-0.14	<0.01-0.38	NA	<0.01-0.04	<0.01-0.12
PESTICIDES/HERBICIDES (ug/L)									
2,4,5-TP	ND-0.2	ND	NA	ND	ND-0.2	NA	ND	NA	NA
Lindane	ND	ND	NA	ND	ND	NA	ND-<0.1	NA	NA
Endrin	ND	ND	NA	ND	ND	NA	ND-<0.1	NA	NA
PURGEABLE HALOCARBONS (ug/L)									
Vinyl Chloride	ND	ND-12.5	ND-178	ND-8.6	ND	ND-9.4	NA	ND	NA
Chloroethane	ND	ND-7.6	ND	ND	ND	ND	NA	ND	NA
Methylene Chloride	ND	ND	ND	ND	ND	ND	NA	ND	NA
Trichlorofluoromethane	ND-3.8	ND-6.8	ND	ND-5.3	ND-5.7	ND-15.7	NA	ND-4.2	NA
1,1-Dichloroethene	ND	ND-8.1	ND-7.5	ND	ND	ND-2.5	NA	ND	NA
1,1-Dichloroethane	ND	ND-4.4	ND	ND-6.8	ND	ND-5.9	NA	ND	NA
1,1,1-Trichloroethane	ND	ND-25.1	ND	ND	ND	ND-2.9	NA	ND-2.9	NA
1,2-Dichloropropane	ND	ND-2.3	ND-2.6	ND	ND	ND	NA	ND	NA
Trichloroethylene	ND-1.4	ND-4290	ND-3280	1870-5000	ND-1.8	ND-362	NA	ND	NA
Tetrachloroethylene	ND	ND-16.3	ND	ND-102	ND	ND-164	NA	ND	NA
Chlorobenzene	ND	ND-3.7	ND	ND	ND	ND	NA	ND	NA
Trans-1,2-Dichloroethene	ND-1.4	ND	ND	ND	ND	ND	NA	ND-0.1	NA
PURGEABLE AROMATICS (ug/L)									
1,4-Dichlorobenzene	ND	ND-9.1	ND	ND	ND	ND-3.9	NA	(very high)	ND
1,2-Dichlorobenzene	ND	ND	ND	ND	ND	ND-4.1	NA	(very high)	ND

NA = not analyzed
ND = not detected

TABLE 3. SUMMARY OF ORGANIC AND INORGANIC COMPOUNDS SURFACE-WATER SAMPLES, CARSWELL AFB, TX

Parameter	Site 4	Site 5	Site 12	Site 16 Oil/Water Separator	Site 16 Unnamed Stream
ORGANIC INDICATORS (mg/L)					
Oil and Grease	NA	<1 - 350	1 - 84,000	1 - 640	<1
Phenols	NA	NA	0.14	NA	NA
TOC	2 - 3	8 - 12	86 - 50,000	4 - 200	4
TOX	NA	NA	<0.01 - 0.63	0.01	0.04
COD	<1 - 4	5 - 9	NA	NA	NA
PECTICIDES/HERBICIDES (ug/L)	ND	ND	NA	NA	NA
PURGEABLE HALOCARBONS (ug/L)					
Vinyl Chloride	ND - 2.3	ND - 38.7	ND	ND	ND
Methylene Chloride	ND - 2.7	ND	ND	ND	ND
Trichlorofluoromethane	ND	ND	ND - 3.5	ND - 2.9	ND - 3.3
1,1,1 Trichloroethane	ND - 5.0	ND	ND	ND	ND
Trichloroethylene	1.4 - 4.3	ND - 4.4	ND	ND	ND
Tetrachloroethylene	ND	ND	ND	ND	ND - 3.4
Trans-1,2-Dichlorethene	ND	ND - 56.9	ND	ND	ND
PURGEABLE AROMATICS (ug/L)	ND	ND	ND	ND	ND
METALS (mg/1)					
Arsenic	NA	NA	<0.06 - 0.16	0.056 - 0.16	0.042
Barium	NA	NA	0.15 - 0.29	0.28 - 0.29	0.25
Cadmium	NA	NA	<0.002 - 0.007	<0.002 - 0.007	<0.002
Chromium	NA	NA	<0.005 - 0.017	<0.005 - 0.017	<0.005
Lead	NA	NA	<0.08 - 0.081	<0.002 - 0.081	<0.002
Mercury	NA	NA	0.0003 - 0.0006	0.0003 - 0.0004	0.0004 - 0.0005
Selenium	NA	NA	<0.08	<0.003	<0.003
Silver	NA	NA	<0.002	<0.002	<0.002

NA = Not analyzed
ND = Not detected

TABLE 4. SUMMARY OF ORGANIC AND INORGANIC COMPOUNDS IN SOIL SAMPLES, CARSWELL AFB, TEXAS

Parameter	Site 1	Site 4	Site 5	Site 10	Site 11	Site 12	Site 13	Site 16	Site 17	Site WSA
ORGANIC INDICATORS (ug/g)										
Oil and Grease	<10 - 210	NA	<10 - 10	<10	<10 - 2200	<10 - 13,000	<10 - 2,000	<10 - 240	<10 - 1,300	<10 - 14
Phenols	<0.1	<0.1 - 0.4	<0.1 - 0.3	NA	<0.1 - <10	<0.1 - 2.4	NA	NA	NA	NA
HERBICIDES (ug/g)										
2,4-D	ND - 0.00052	NA	ND	NA	ND	NA	NA	NA	NA	NA
PESTICIDES (ug/g)	ND	NA	ND	NA	ND	NA	NA	NA	NA	NA
PURGEABLE HALOCARBONS (ug/g)										
Trichlorofluoromethane	ND	NA	ND	ND	ND	ND - 0.210	NA	ND	NA	ND
1,1,1 Trichloroethane	ND	NA	ND	ND - 0.044	ND	ND	NA	ND	NA	ND
Trichloroethylene	ND	NA	ND - 0.338	ND - 0.067	ND - 0.257	ND - 0.395	NA	ND	NA	ND - 0.0619
Tetrachloroethylene	ND	NA	ND	ND	ND	ND	NA	ND	NA	ND
Trans-1,2-Dichlorethene	ND	NA	ND - 0.033	ND	ND	ND	NA	ND	NA	ND
1,2-Dichlorobenzene	ND	NA	ND	ND	ND	ND - 1.659	NA	ND	NA	ND
1,3-Dichlorobenzene	ND	NA	ND	ND	ND	ND - 0.464	NA	ND	NA	ND
1,1,2,2-Tetrachloroethane	ND	NA	ND	ND	ND	ND - 1.000	NA	ND	NA	ND
PURGEABLE AROMATICS (ug/g)										
Benzene	ND	NA	ND	ND	ND	ND - 752.0	NA	ND	NA	ND
Ethyl Benzene	ND	NA	ND - 1.070	ND	ND	ND - 110.0	NA	ND	NA	ND
Toluene	ND	NA	ND - 0.460	ND	ND	ND - 134.0	NA	ND - 0.54	NA	ND
METALS (ug/g)										
Arsenic	<3 - 11	<5.1 - 9.4	<5.8 - 9.4	NA	<3 - 14	<3 - 19	<0.06 - 0.19	<5.8 - 11	NA	NA
Barium	16 - 48	2.6 - 50	2.8 - 70	NA	<0.23 - 47	4.4 - 100	0.37 - 1.2	45 - 85	NA	NA
Cadmium	<0.39 - <0.40	<0.17 - 0.64	<0.19 - 0.62	NA	<0.2 - <0.4	<0.16 - 0.69	<0.002 - 0.031	<0.2 - 0.89	NA	NA
Chromium	1.8 - 22	0.44 - 4.8	0.74 - 47	NA	2.0 - 7.9	1.4 - 15	<0.005 - 0.022	5.1 - 13	NA	NA
Lead	<4.0 - 10	<6.3 - 8.3	<7.8 - 8.4	NA	<4 - 13	<4 - 54	<0.08 - 0.12	3.6 - 20	NA	NA
Mercury	<0.05 - 0.17	<0.04	<0.05 - 0.21	NA	0.08 - 0.21	<0.04 - 0.21	0.0003 - 0.13	0.05 - 0.10	NA	NA
Selenium	<4.0 - 17	<6.0 - <7.6	<7.7 - <7.9	NA	<4 - 20	<4 - 38	<0.08 - 0.18	9.1 - 41	NA	NA
Silver	1.0 - 2.1	<0.19 - 2.0	<0.20 - 1.0	NA	<0.18 - 3.1	<0.16 - 2.8	<0.002 - 0.027	0.82 - 1.2	NA	NA

NA = Not analyzed
ND = Not detected

areas near these sites. Most of the contamination is centered east of these sites at the golf course, however, levels of TCE in the range of 10-3,280 ug/L were also discovered in the ground water upgradient of Landfill 5, 900 feet from the flightline.

Site 11: Low levels of TCE (range from none detected to 0.249 ug/g) were detected in one well at Site 11, located just north of landfill 5. In addition, TCE (range from none detected to 0.257 ug/g) was also detected in soil from a hand-augered boring at the center of the site and at the upgradient well.

Site 12: Results of analyses at Site 12 indicate that the fire training activities have introduced significant amounts of halogenated and aromatic organic compounds into soil (range from none detected to 752 ug/g) and ground water (range from none detected to 362 ug/L). The highest levels of contamination occur in the center of the site, where high levels of benzene, toluene, and ethyl benzene were detected (range from none detected to 752 ug/g, 134 ug/g and 110 ug/g, respectively) in soil. TCE also occurs in ground water downgradient (north and east) of the site, but in lower concentrations (range from none detected to 362 ug/L) than at Sites 4, 5, and 10. The operations at this site have also affected the quality of surface water draining the area. Water samples from a drainage ditch near the site had oil and grease (range from 1 to 84,000 mg/L) and TOC (range 86 to 50,000 mg/L).

Site 13: Soils at the Flightline Drainage Ditch are contaminated with jet fuel, detergents, or both. It was observed that the distribution of contaminants is somewhat erratic, suggesting that contaminant mobility and infiltration are controlled by local variations in soil composition and texture.

Site 15: Pesticides and herbicides from the former Entomology Building and Entomology Dry Well have not been released in significant quantities into the soil and water. Lindane and endrine were detected in one downgradient well, but at levels which were not quantitatively measurable.

Site 16: Hydrocarbon fuels (gasoline or JP-4) were observable (range of oil and grease was <1 to 7,100 mg/L, with high levels of aromatic compounds) in the ground water at Site 16. The source of the contamination is either a former gasoline station at the site or the POL Tank Farm. Results of analyses at the Unnamed Stream suggest that the oil/water separator does not always ensure that oil and grease are not released to the stream.

Site 17: Organic compounds were observed in the ground water (<1 to 31,000 mg/L) and soil (<1 to 1,300 ug/g) underlying the POL Tank Farm. The organic compounds are most likely fuel hydrocarbons from the storage and handling of fuels. One water sample from borehole 17D suggests that organic solvents (i.e., TOX) may be present in the ground water. The low level (TOX of 0.12 mg/L) observed could be an interference since it was not observed in the other seven wells.

WSA Site: Ground water from the potable supply well was found to contain total radium (8.5 pCi/L) in excess of federal standards for drinking water. In addition, analysis of soil west of the Inspection Shop site revealed the presence of TCE (range from none detected to 0.0619 ug/g).

Recommendations

Based on the findings of this study, follow-up investigations are recommended to resolve issues defined by the Phase II Stage 1 work. These recommendations and issues addressed are listed in Table 5, in order of priority. In addition to these recommendations for future investigation, the Flightline Drainage Ditch (Site 13) is recommended for remedial action.

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TABLE 5. PRIORITY OF RECOMMENDED STAGE 2 SITES AND ACTIONS, CARSWELL AFB, TEXAS

Priority	Site(s)	Rationale	Summary of Recommended Actions
Highest	4, 5, 10, 12	High TCE levels in ground water	Install additional monitor wells to define contamination plume. Conduct sampling and analysis of ground water
		Excessive benzene and toluene levels in soil	
		Continued opportunity for introduction of contamination	Determine if soil vapor plume is present
			Define transmissivity of upper zone.
High	16, 17	High levels of organic compounds in ground water	Install monitor wells to define containment plume; sample and analyze ground water
		Proximity of Farmers Branch as a receptor	Define ground water flow characteristics and upper zone transmissivity
Middle/ Low	1, 3, 11, 15 WSA	Minor or no ground water contamination	Continue monitoring at existing wells
		No ground water data at Landfill 3	Install two wells at Landfill 3
		Proximity of Sites 15 and 11 to higher priority sites	Install wells at WSA

1.0 INTRODUCTION

The Department of Defense (DOD) is conducting a nation-wide program to evaluate past waste disposal practices on DOD property, to control the migration of hazardous contaminants, and to control hazards that may result from these waste disposal practices. This program, the Installation Restoration Program (IRP), consists of four phases: Phase I, Initial Assessment/Records Search; Phase II, Problem Confirmation/Quantification; Phase III, Technology Base Development and Phase IV, Operations. The United States Air Force has initiated an IRP investigation at Carswell Air Force Base near Fort Worth, Texas; Radian Corporation has performed the Phase II (Stage 1) Field Evaluation under USAF Contract No. F33615-84-D-4402, Delivery Order 0006.

1.1 Purpose of the Investigation

The purpose of the Phase II (Stage 1) investigation was to determine if environmental contamiantion has resulted from past waste disposal practices at Carswell AFB. In addition, the purpose of the investigation was to estimate the magnitude and extent of contamination, to identify environmental consequences of migrating pollutants, and to recommend additional investigations to identify the magnitude, extent and direction of movement of discovered contaminants.

1.2 Duration of the Program

Authorization to proceed on the Carswell AFB Phase II (Stage 1) program was given on 29 September 1984. Field activities were started during December 1984 after an initial site visit (21 November 1984) and after field safety and sampling plans were developed. The field work consisted of geophysical surveys, coring and sampling of near-surface soil at several locations, installation of upper zone and Paluxy ground-water monitor wells, sampling of surface water, and sampling of ground water from completed wells and borings.

1.3 Location and Site Descriptions

Carswell AFB is located on 2,700 acres of land in Tarrant County, Texas (Figure 1-1). The city of Fort Worth surrounds most of the base, with the suburban communities of White Settlement, River Oaks, Westworth Village, and Westover Hills also located adjacent to the base (Figure 1-2). Carswell is bounded to the north and east by the West Fork of the Trinity River, part of which is dammed to form Lake Worth along the northern boundary of the base. Air Force Plant 4, an aircraft assembly plant owned by the Air Force and operated by General Dynamics, is directly west of the base.

Phase II (Stage 1) work at Carswell AFB has focused on eleven sites on base shown on Figure 1-2 and the WSA, located eleven (11) miles west of the base. These sites consist of landfills, fire training areas, industrial areas, and spill sites. The following paragraphs provide brief descriptions of the locations and features of the Phase II sites. All of the information provided was obtained from the Installation Restoration Program Phase I record search report (CH_2M-Hill, 1984).

Site 1, Landfill 1

Landfill 1 was reported to be the original base landfill and was operated during the 1940s. This site is located adjacent to the Trinity River levee at the same spot as the current Defense Reutilization and Marketing Office (DRMO) storage yard. Due to the time elapsed since this site was closed, no information was available concerning past waste disposal practices at this location.

Site 3, Landfill 3

Landfill 3 is located under the present runway, immediately south of the culvert carying the flow of Farmers Branch. Dring the period from 1950 until 1952, Site 3 was used for burial of all types of wastes, but primarily construction rubble. During that period, the runway ended north of Farmers Branch, and a ravine present at this site was used as a fill area.

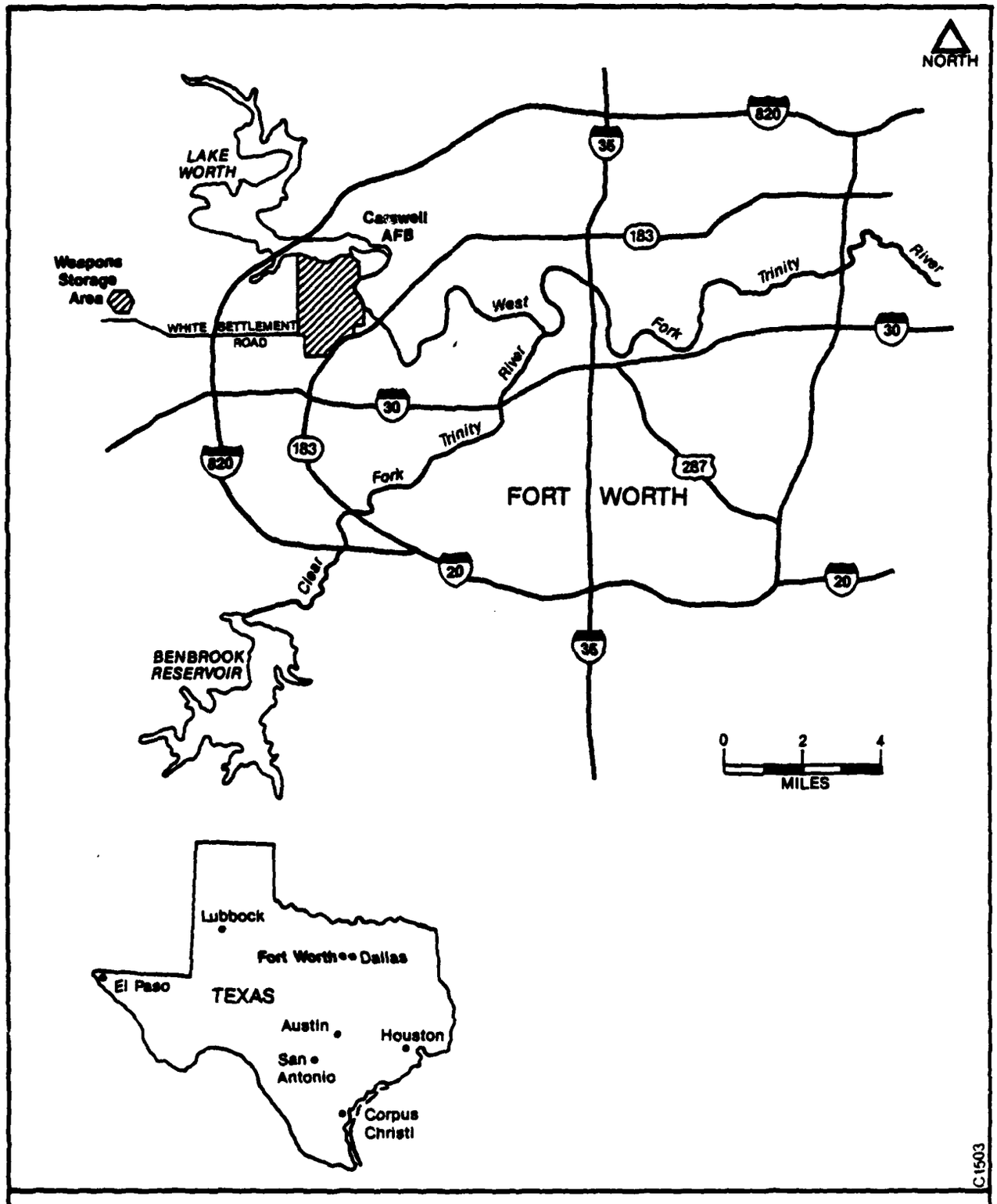

Figure 1-1. Regional Setting of Carswell AFB, Texas.

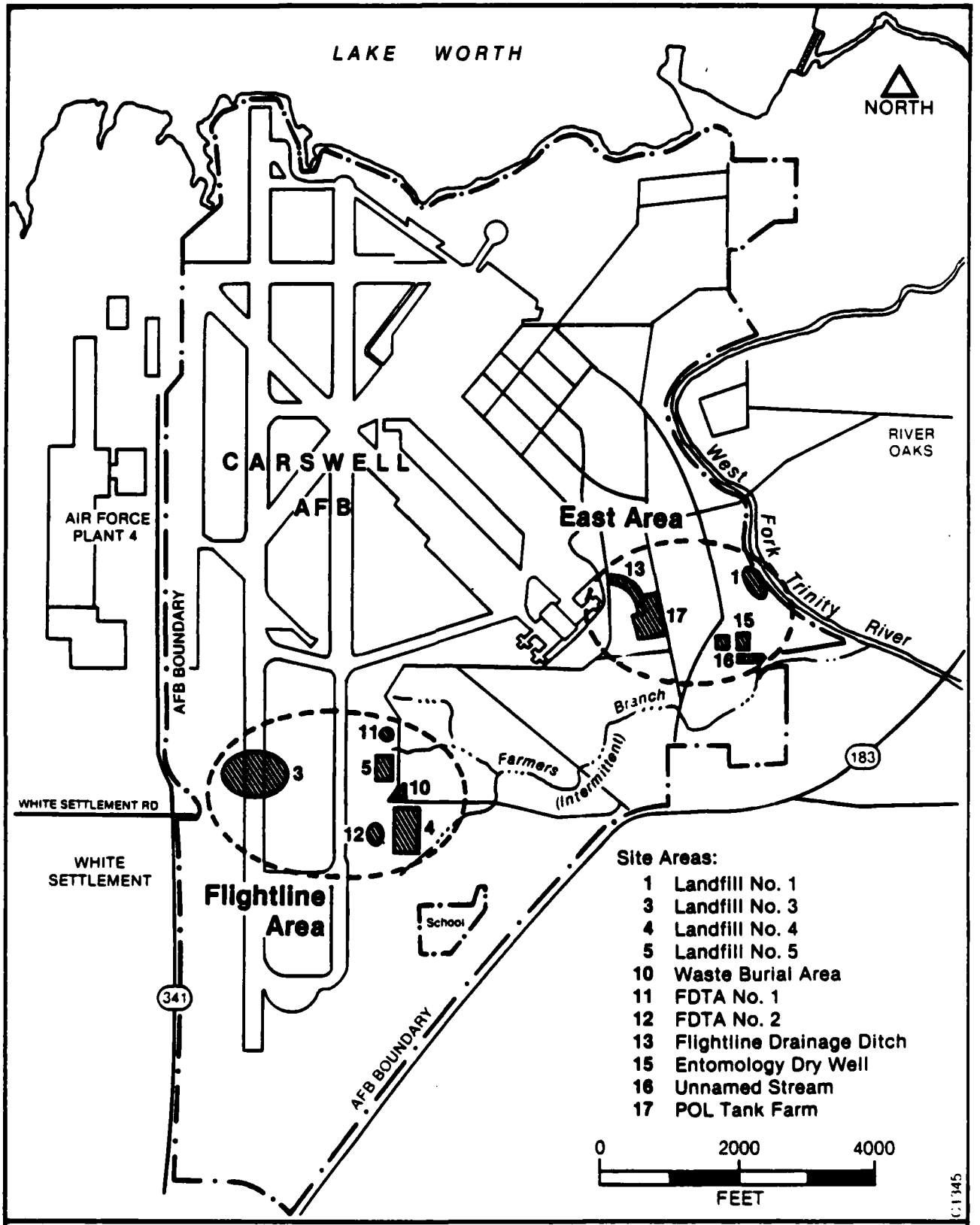

Figure 1-2. Location of Phase II, Stage 1 Sites, Carswell AFB, Texas.

Site 4, Landfill 4

Landfill 4 was operated from approximately 1956 until 1975. This site, which includes 10 acres of land east of the runway and is currently the location of the radar site, was the main landfill during much of the history of Carswell AFB. All base refuse was buried here and burning was a regular practice. At least six large pits, approximately 12 feet deep were filled with refuse which was burned and buried. Various materials suspected of being hazardous were reportedly disposed at this site, including drums of waste liquids, partially full paint cans, and cadmium batteries. Written records indicate that routine disposal of waste paints, thinners, and strippers; oil containing adsorbent materials; PD-680 (a safety cleaning solvent) and oils may have been practiced at this location.

Site 5, Landfill 5

Landfill 5 was reportedly used between 1963 and 1975. This site is located northwest of Landfill 4 and was constructed adjacent to a small tributary to Farmers Branch. The landfill site was constructed by building a clay berm adjacent to the creek and then filling the area behind the berm up to its existing level. This fill site received all types of flightline wastes and refuse, and was regularly burned prior to covering.

Site 10, Waste Burial Area

Site 10, located adjacent to and north of White Settlement Road, where it dead-ends at the taxiway, was used for burial of wastes during the 1960s. Various types of hazardous materials, including drums of cleaning solvents, leaded sludge, and possibly ordnance materials, were reported disposed of at this site. Reportedly, these materials were buried in a natural impermeable clay strata. The site is currently identified by several signs reporting the presence of buried tetraethyl lead sludge.

Site 11, Fire Department Training Area 1

Site 11 was located near Landfill 5. This training area was the primary fire pit prior to 1963. The pit reportedly was adjacent to a small tributary to Farmers Branch, was gravel-lined, and had a low concrete curb around its perimeter. Several fire training exercises are reported to have taken place at this site each month, with waste oils and contaminated fuels being the primary flammable liquids used in the exercises. Small quantities of solvents are also reported to have been used in these exercises.

Site 12, Fire Department Training Area 2

Site 12 is located between the north-south taxiway and the radar facility. This site, with only slight modifications, has been used as a fire department training area since 1963. The fire ring is gravel-lined with a low earthen berm around its perimeter. In the past, a pit was present at the site to collect runoff from training exercises, but this pit has been filled. At the beginning of Phase II, Stage 1 field work, the berm had been breached by erosion and some runoff collects outside the northeast corner of the ring. By the conclusion of field work, the breach had been repaired.

Two tanks located at the site have been used for storage of flammable liquids prior to training exercises. An 8,500-gallon aboveground tank is used to store clean or contaminated fuels, which are delivered to the ring via a pump and various pipes. An underground tank of approximately 9,500 gallons has been used for storage of waste oils and solvents from the flightline shops. Although normal disposition of the underground tank contents has been to off-base contractors, it is possible that contents of this tank have also been used for training exercises in the past.

Site 13, Flightline Drainage Ditch

Site 13 is located across Haile Drive, directly east of the main base washrack (Pad 29) and Hangars 1049 and 1048. The ditch is unlined from

Haile Drive to where it intersects the POL tank farm, at which point it enters a concrete-lined channel. Visible evidence of contamination was present at Site 13 during the base visit in the form of a white liquid (aircraft soap) originating at the washrack and entering the ditch through a small pipe; the presence of petroleum products on the surface of the water further downstream; and the presence of a dark zone of fuel or oil saturation along the banks of the ditch at least 10 inches above the surface of the water.

In addition to normal storm drainage, this ditch receives discharges from the aircraft washracks (18 and 29) and discharges from the Fuel Systems Shop (Building 1048). Washrack wastes (PD-680, a cleaning solvent, and soap) can be discharged directly to the Facility 1190 oil/water separator, located adjacent to the flightline drainage ditch, or into the drainage ditch via an overflow pipe in the drain line between the washracks and the oil/water separator. Discharge to the oil/water separator or to the drainage ditch is controlled by a valve in the drain line just upstream of the separator.

Discharges from the Fuel Systems Shop consists of JP-4 fuel drained from fuel tanks. Prior to 1978, this fuel was piped via gravity to the Facility 1190 oil/water separator. The pipe was routed through the much larger stormwater culvert that begins the flightline drainage ditch. Approximately 5 years ago, the pipe ruptured and JP-4 was allowed to enter the stormwater culvert and thus the ditch. The pipe was repaired in March 1984 and is functioning properly.

Site 15, Entomology Dry Well

Site 15 is located immediately west of the old entomology shed (Building 1338), in the present Civil Engineering Compound, off Rogner Drive. A dry well at the site was used for disposal of insecticide rinsate between 1965 and 1981. The site is currently vacant; Building 1338 has been demolished and the site has been regraded. Building 1338 was used for the storage and mixing of insecticides including malathion, diazinon, dursban, and chlordane, and for storage and cleaning of spray equipment. Chlordane has been

reported in samples taken from the well next to Building 1338, although no documented analytical results could be found during the records search to substantiate this report.

Site 16, Unnamed Stream

Site 16 is a small tributary of Farmers Branch, located south of the old entomology shed, and near the confluence of Farmers Branch and the Trinity River. This small stream is the discharge from an oil/water separator located immediately south of the fenced civil engineering yard, and receives it perennial flow from ground water entering the separator. The separator is connected to a french underdrain system which was reportedly built in 1965 to capture POL leaking from the POL Tank Farm (see below) into the sewer pipes. This separator has not been routinely cleaned for a number of years and contained hydrocarbon constituents. Overflow from this separator is apparently contributing POL and iron to the little stream. The discharge stream has a petroleum odor, an oil sheen, and is reddish brown with extensive growths of what appears to be iron-reducing bacteria. Previous analyses completed on the stream have detected trace quantities of trichloroethylene.

Site 17, POL Tank Farm

Site 17 is located on the eastern side of Carswell AFB, adjacent to Knight's Lake Road. Currently, three above-ground tanks are located at this location with a fourth under construction; formerly, three additional tanks were also located here. During the early 1960s, fuels were discovered in the ground in this area, and also downgradient from this site. A french drain system was installed downgradient from this area to collect fuels in the ground. The french drain discharged through the oil/water separator mentioned above under Site 16. At that same time, the underground leaking POL pipes were reportedly located and replaced. No additional loss of POL to the ground is suspected to have occurred in this area since 1965. The french drain system is still continuing to collect POL as evidenced by the contents of the Unnamed Stream observed during the site visit. As a result, fuel is still suspected to be present in the ground in the area of the POL tank farm and downgradient (southeast and east) from it.

Weapons Storage Area (WSA)

The WSA is located about 11 miles west of Carswell AFB, just north of White Settlement Road (Figure 1-1). Facilities at the WSA include two munitions inspection shops, 16 ordnance storage buildings, one entry control building, an emergency power plant, an Explosive Ordnance Disposal range, a radioactive waste disposal facility, a water storage tank, and two water wells.

It has been reported that waste cleaners and solvents (suspected paint thinners and trichloroethene) have occasionally been disposed of on the ground behind the Inspection Shop. Quantities were estimated to be 5 to 10 gallons per year.

1.4 Waste Disposal Practices

The Phase I report (CH2M Hill, 1984) has an account of the history of waste generation and disposal activities. The following paragraphs describing the waste disposal history are from the Phase I report.

Wastes have been generated and disposed of at Carswell AFB since the beginning of industrial operations in 1942. The major industrial operations at Carswell AFB now include: maintenance of jet engines, aerospace ground equipment (AGE), fuel systems, weapons systems, and pneudraulic systems; maintenance of general and special purpose vehicles; aircraft corrosion control; and non-destructive inspection (NDI) activities. All of these operations generate wastes: primarily oils, recoverable fuels, spent solvents, and cleaners.

The total quantity of waste oils, recoverable fuels, spent solvents, and cleaners generated at Carswell AFB is estimated to be approximately 55,000 gallons/year. This estimate was derived from a review of shop files and the best recollection of interviewees and is considered to be representative of the 1970s to 1983. Prior to the 1970s, the waste quantities were probably less because fewer aircraft were maintained at the base.

Prior to about 1970, some of the liquid waste oil, recovered fuels and possibly solvents were burned at two fire training areas at the Base. Both sites have been described as "gravel-lined", with one being used from 1942 to 1963 and the second used since 1963. It is estimated that up to 15,000 gallons per year of waste oils, fuels, solvents and cleaners have gone to the fire training area before 1970. After 1970 the training exercises have been conducted about 2 to 3 times per month using an average of 1,300 gallons per month of clean or recovered JP-4 fuel.

Smaller amounts of liquid wastes are associated with pest and weed control activities at the Base. The pesticides have been stored at two locations, one at Facility 1338 before 1981 and thereafter at Facility 1217. Some of the chemicals in use are anticoagulant, Baygon, diazinon, malathion organophosphate and monosodium arenate. Used containers are triple rinsed, punctured and disposed of in dumpsters along with the empty bags. Rinse waters from container and equipment rinsing is discharged to a tank outside Facility 1217. The full tank is pumped out for proper disposal. Before 1981, the rinse waters were discharged into a "dry well" sump located outside Facility 1338. This "dry well" sump has been identified as a potentially contaminated site.

Practices for past and present industrial waste disposal are summarized below:

- 1942-1970: The majority of waste oils, recovered fuels, spent solvents, and cleaners were burned at the fire department training areas during practice exercises. Some waste oils and spent solvents were disposed of through contractor removal, while some waste paints (contaminted with thinners and solvents), waste oils, and PD-680 are suspected of having been disposed of in the base landfills. Some waste oils, recovered fuels, spent solvents, and cleaners were also discharged to sanitary and storm

sewers. These discharges occurred primarily at the washracks. In 1955, an oil/water separator (Facility 1190) was installed to recover waste materials discharged from the washracks. Materials from the oil/water separators were pumped out and disposed of through contractor removal. Discharge from the oil/water separator was and still is into the sanitary sewers.

- 1970-1975: During this period, most waste oils, spent solvents, and cleaners were disposed of by contractor removal. A private contractor would pump the materials from oil/water separators and from 55-gallon drums and bowsers. Recovered JP-4 was still stored at the fire department training area and burned in practice exercises. Recovered JP-4 was also reused by AGE. Some waste paints (contaminated with thinners and solvents), waste oils, and PD-680 are supected of having been disposed of in the base landfills. Some waste oils, solvents, and cleaners were discharged into sanitary drains. This primarily occurred at the washracks that discharge to the Facility 1190 oil/water separator. This oil/water separator was routinely pumped out by a private contractor and the recovered materials removed from the base by the contractor.

- 1975-1982: The majority of waste oils, spent solvents and cleaners were disposed of by service contract either directly or through the Defense Reutilization and Marketing Office (DRMO). Recovered JP-4 was stored at the fire department training area and burned during practice exercises. Recovered JP-4 was also used by AGE. PD-680 used at the washracks was discharged to the Facility 1190 oil/water separator which discharges to the sanitary sewers.

- o 1982-Present: Waste oils, solvents, and cleaners are collected in 55-gallon drums and temporarily (less than 90 days) stored at 12 hazardous waste accumulation points located throughout the flightline area. They are subsequently disposed of by contractor removal through DRMO. Recovered JP-4 fuel is stored at the fire department training area for subsequent burning in practice exercises or is reused by AGE. Removal of waste oils and PD-680 (Type II) from oil/water separators is also handled by an off-base contractor through DRMO.

1.5 Sampling and Analytical Program

The sampling program at Carswell AFB consisted of the collection of stream sediments, soils, surface water, and ground water. Stream sediments and surface water were collected as grab samples. Soil samples were collected with a hand-operated auger at some sites and with a hydraulic-powered split-spoon sampler during drilling activities. All soil samples were placed individually in glass jars and frozen. Ground-water samples were collected from the alluvial monitor well using a Teflon bailer. Permanently installed electric pumps were used to collect ground water from the Paluxy monitor wells and from the Weapon Storage Area well. All water samples were chilled to 4°C. In addition, samples collected for TOC, phenols, COD, and oil and grease analysis were preserved with sulfuric acid (H_2SO_4) to pH<2. Samples for metals analysis were collected in plastic bottles and preserved with nitric (HNO_3) acid to pH<2.

All samples were shipped to Radian Analytical Services for analysis. The schedule of analyses is summarized on Table 1-1 with complete descriptions provided in Section 3.0.

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TABLE 1-1. ANALYTICAL SCHEDULE FOR SOIL AND WATER SAMPLES, ( ) ELL AFB, TEXAS

Parameter	Sites[1] 1	4	5	10	11	12	13	15	16	17	WSA
Total Organic Carbon	W	W	W	W	W	W		W	W	W	
Total Organic Halogen	W	W	W	W	W	W			W	W	
Oil and Grease	W,S	W	W,S	W,S	W,S	W,S	S		W,S	W,S	S
Lead									W,S		
EP Toxicity							S				
Pesticides	W,S	W	W,S		W,S			W,S			
Phenols	W,S	W,S	W,S		W,S	W,S					
Heavy Metals	W,S	W,S	W,S		W,S	W,S					
Purgeable Organics (Methods 601, 602)	W,S	W	W,S	W,S	W,S	W,S			W,S		S
COD		W	W								
Radiochemistry											W

[1] W = Water, S = Soil.

1.6 Investigation Personnel

The Carswell AFB IRP Phase II (Stage 1) investigation was conducted by several individuals from the Austin office of Radian Corporation. Thomas W. Grimshaw, Program Manager, was responsible for the contractual administration of the program. The overall technical program was directed by Lawrence N. French, Senior Geologist and Certified Professional Geological Scientist. Mr. French coordinated all activities of the program, including direct participation with USAF personnel in the areas of contract and technical matters. The geophysical surveys and monitor well installation were supervised by Mr. French and Jenny B. Chapman, Geologist. Sediment sampling activities were conducted by Mr. French, James L. Machin, and Peter A. Waterreus. Surface-water sampling activities were conducted by Mr. French and Mr. Machin. Monitor well sampling activities were conducted by Mr. French, Ms. Chapman, Mr. Waterreus, David H. Gancarz, and Doug Orr. Mr. French and Ms. Chapman were the principal authors of the draft report. Cartographic and technical illustrations were prepared by Jill P. Rossi and Kevin L. Zonana. William M. Little provided senior technical staff review and editing. All of the above individuals were involved in the preparation of the draft report. Resumes for these individuals are provided in Appendix J.

2.0 ENVIRONMENTAL SETTING

The following discussion of the Carswell AFB environmental setting is derived primarily from the Installation Restoration Program Phase I Records Search Report (CH2M Hill, 1984). Information from that report is supplemented by information from the literature and from the general findings of this study. The following sections describe the environmental setting of Carswell AFB. Basic features and history of the sites investigated in this study are also discussed below.

2.1 General Geographic Setting and Land Use

Carswell AFB is located in northeastern Texas in Tarrant County, six miles west of downtown Fort Worth (Figure 1-1). The base is bordered by Lake Worth to the north, the West Fork of the Trinity River and the community of Westworth to the east and southeast, the community of White Settlement to the south and southwest and AF Plant 4 to the west. The location of Carswell AFB is shown in Figure 2-1. One off-base facility, the Weapons Storage Area (WSA), is included in this study. The WSA location, 11 miles west of Carswell AFB on White Settlement Road, is also shown in Figure 1-1.

The base lies within an area of primarily residential, recreational, and industrial/commercial land use. The principal industrial use of the area is Air Force Plant 4, an aircraft production plant that borders Carswell AFB to the west and shares the runway with the base. Recreational land use includes the Y.M.C.A.'s Camp Carter, and various parks on the shores of Lake Worth.

2.2 Physiographic and Topographic Features

The majority of Carswell AFB is located within the Grand Prairie section of the Central Lowlands Physiographic Province. This area is characterized by broad terrace surfaces sloping gently eastward, interrupted by

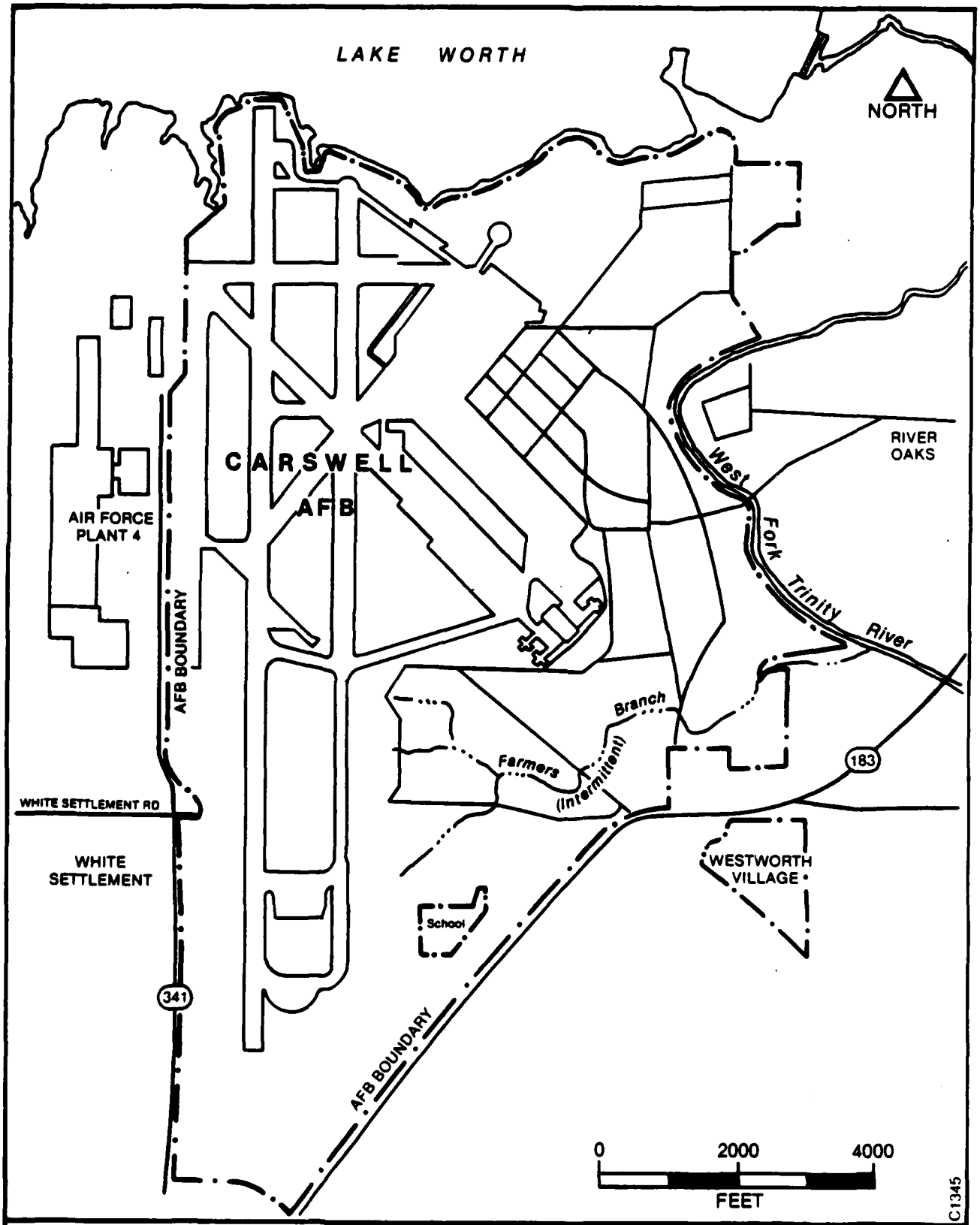

Figure 2-1. Area Location Map of Carswell AFB, Texas.

westward-facing escarpments. The land is typically grass covered and treeless, except for isolated stands of upland timber. The northwestern part of Carswell AFB is within the Western Cross Timbers Physiographic Province that is characterized by rolling topography and a heavy growth of post and blackjack oaks.

The topography of the base is fairly flat except for areas near Farmer's Branch and the Trinity River. Land surface slopes gently northeast toward Lake Worth and east toward the West Fork of the Trinity River. Elevations on base range from a high of approximately 690 feet mean sea level (msl) at the southwest corner of the base to a low of approximately 550 feet msl at the east side of the base. The elevation of Lake Worth usually approximates the elevation of the dam spillway, 594 feet msl.

The principal drainage for Carswell AFB is the West Fork of the Trinity River. Farmers Branch drains the southern portion of the base, but in turn discharges into the Trinity. A small portion of the north end of the base drains into Lake Worth.

2.3 Geologic and Hydrogeologic Conditions

Surficial Soils

The U. S. D. A. Soil Conservation Service has identified four soil associations at Carswell AFB. The soils are described in Table 2-1 and their occurrences on base are shown on Figure 2-2. The surficial soils of the installation area are primarily nearly level to gently sloping clayey soils of the Sanger-Purves-Slidell and Aledo-Bolar-Sanger Associations. In addition to the above, the clayey soil of the Frio-Trinity Association and the loamy soil of the Bastsil-Silawa Association occur on the floodplain and stream terraces of the West Fork of the Trinity River.

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TABLE 2-1. SOIL ASSOCIATIONS FOR CARSWELL AFB, TX

Association	Description	Thickness (inches)	Permeability (cm/sec)
Sanger-Purves-Slidell: Clayey soils of nearly level to gently sloping uplands.	Clay loam Clay over bedrock Silty clay	8-80	$<4.2 \times 10^{-5}$ to 3×10^{-4}
Aledo-Bolar-Sanger: Loamy and clayey soils of gently sloping to moderately steep uplands.	Clay loam over bedrock Clay loam	8-70	$<4.2 \times 10^{-5}$ to 9×10^{-4}
Frio-Trinity: Clayey soil on nearly level flood plains.	Silty clay loam Clay	25-75	$<4.2 \times 10^{-5}$ to 3×10^{-4}
Bastsil-Silawa: Loamy soils on nearly level to sloping stream terraces.	Sandy clay loam	40-80	9×10^{-4} to 3×10^{-3}

SOURCE: U.S. Department of Agriculture, 1981, Soil Survey of Tarrant County: Soil Conservation Service, 218 pp.

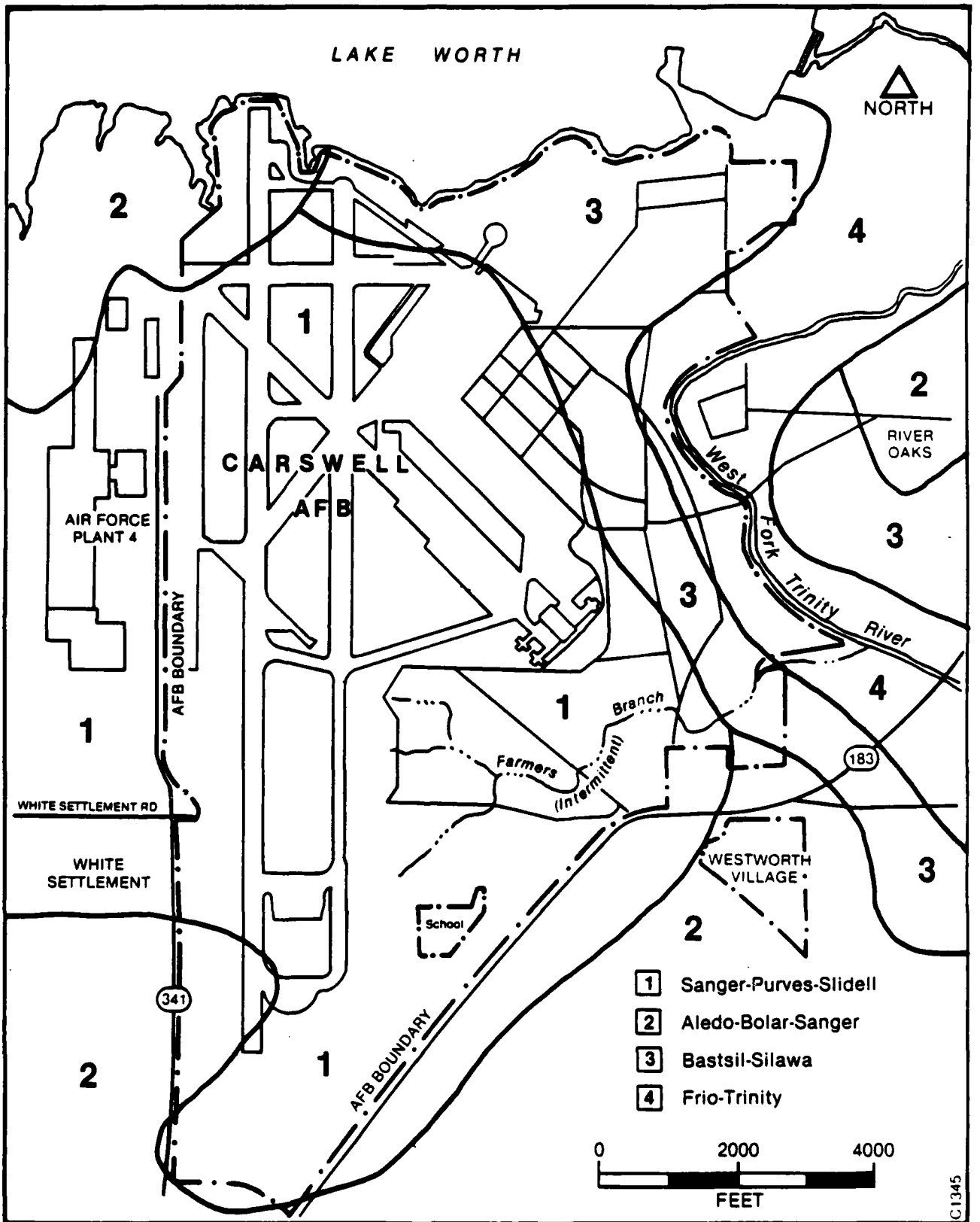

Figure 2-2. Soils Association Map, Carswell AFB, Texas.

Lithology

A geologic section showing the rock formations beneath Carswell AFB is presented in Figure 2-3. Descriptions and properties of units pertinent to this study are summarized in Table 2-2. From youngest to oldest, the geologic units of interest to Carswell AFB are as follows: 1) Quaternary Alluvium, 2) Cretaceous Goodland Limestone, 3) Cretaceous Walnut Formation, 4) Cretaceous Paluxy Formation, 5) Cretaceous Glen Rose Formation, and 6) Cretaceous Twin Mountains Formation. The occurrence of these units on base is shown on a geologic map, Figure 2-4.

The majority of the base is covered by alluvium deposited by the Trinity River during flood stages. The alluvium is composed of gravel, sand, silt, and clay of varying thicknesses and lateral extents. The Goodland Limestone is exposed on the southern portion of the base, south of White Settlement Road. The Goodland is a chalky-white, fossiliferous limestone and marl. A small area exposing the Walnut and Paluxy Formations occurs in the northwestern corner of the base along the shores of Lake Worth. The Walnut Formation is a shell-agglomerate limestone with varying amounts of clay and shale. The Paluxy Formation is primarily a fine- to coarse-grained sand with minor amounts of clay, sandy clay, pyrite, lignite, and shale. Neither the fine-grained Glen Rose Limestone, nor the sandstones of the Twin Mountains Formation are exposed at Carswell AFB, though these formations are important in understanding the hydrogeology of the Carswell area.

Structure

Carswell AFB is located on the relatively stable Texas craton, west of the faults that lie along the Ouachita Structural Belt. No major faults or fracture zones have been mapped near the base. The regional dip of the rocks beneath Carswell AFB is between 35 and 40 feet per mile in an easterly to southeasterly direction. The stratigraphic and structural relationships of the uppermost geologic units at Carswell AFB are illustrated in Figure 2-5, which shows a cross-section from Site 12 eastward to the Trinity River at Site 1.

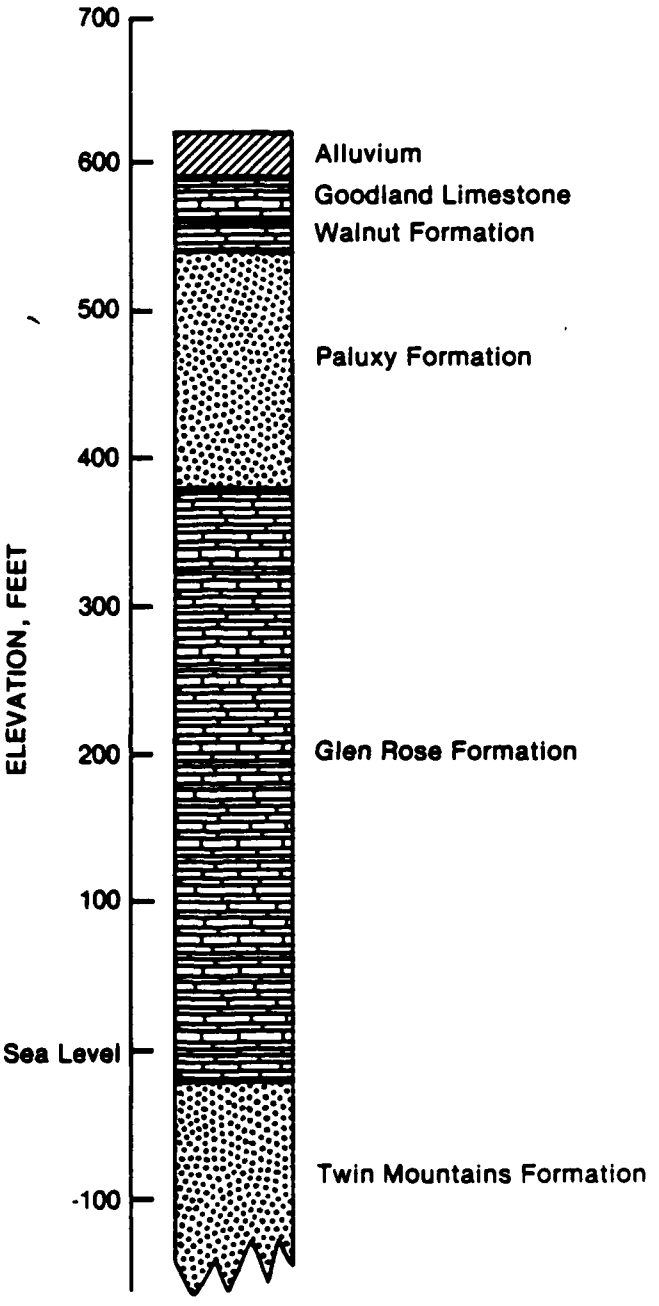

Figure 2-3. Stratigraphic Column at Carswell AFB, Texas.

TABLE 2-2. GEOLOGIC FORMATIONS BENEATH CARSWELL AFB, TEXAS

System	Series and Group	Formation and Member	Thickness (ft)	Character of Rocks	Topographic Expression	Water-Bearing Properties
Quaternary	Recent and Pleistocene	Alluvium	0-45	Sand, gravel, clay, and silt.	Terrace and flood-plain deposits.	Small to moderate yields. Water unsatisfactory for use unless treated.
Cretaceous	Comanche Series Washita Group	Duck Creek Formation	0-90	Impure limestone and marl, which is blue when fresh and straw-colored when weathered. Fossiliferous with distinctive ammonites.	Bench topography produced by lower limestone unit. Upper marl forms slope separating the Duck Creek from Fort Worth limestone.	Small to moderate yields. Water unsatisfactory for use unless treated.
	Comanche Series Fredericksburg Group	Kiamichi Formation	0-40	Blue and brownish-yellow marl, thin limestone and sandstone flags.	Grassy slope separating scarps of Goodland and Duck Creek formations.	Small to moderate yields. Water unsatisfactory for use unless treated.
		Goodland Limestone	0-130	Chalky-white fossiliferous limestone, and blue to yellowish brown marl.	Prominent glaring-white escarpment along streams.	Small to moderate yields. Water unsatisfactory for use unless treated.
		Walnut Clay	0-20	Shell agglomerate fossiliferous clay and limestone, sandy clay, and black shale.	Forms conspicuous escarpment and waterfalls in western Cross Timbers belt.	Not known to yield water to wells in Tarrant County.
				UNCONFORMITY		
Cretaceous	Comanche Series Trinity Group	Paluxy Sand	140-180	Fine-grained sand, shale, sandy shale, lignite and pyrite.	Sandy soil, hummocky topography, heavily wooded with oaks.	Source of supply for most households, smaller cities, and some industries.
		Glen Rose Limestone	250-450	Fine-grained limestone, shale, marl, and sandstone.	Not exposed in Tarrant County.	Sands yield small supplies to wells in Fort Worth and western Tarrant County. Water too highly mineralized east of Fort Worth.
		Twin Mountains Formation (Formerly Travis Peak Formation)	250-450	Coarse to fine-grained sandstone, red shale, red and yellow clay at base.	Not exposed in Tarrant County.	Principal aquifer in Tarrant County. Yields large supplies for municipal and industrial purposes. Water in upper sands east of Fort Worth may be highly mineralized.
				MAJOR UNCONFORMITY		
Pennsylvanian	Undifferentiated		6,000-7,000	Gray, sandy shale, tight quartzitic sandstone, black limestone. Probably represents Strawn formation.	Not exposed in Tarrant County.	Not tested. Probably would not yield fresh water.

Source: E.R. Leggat.

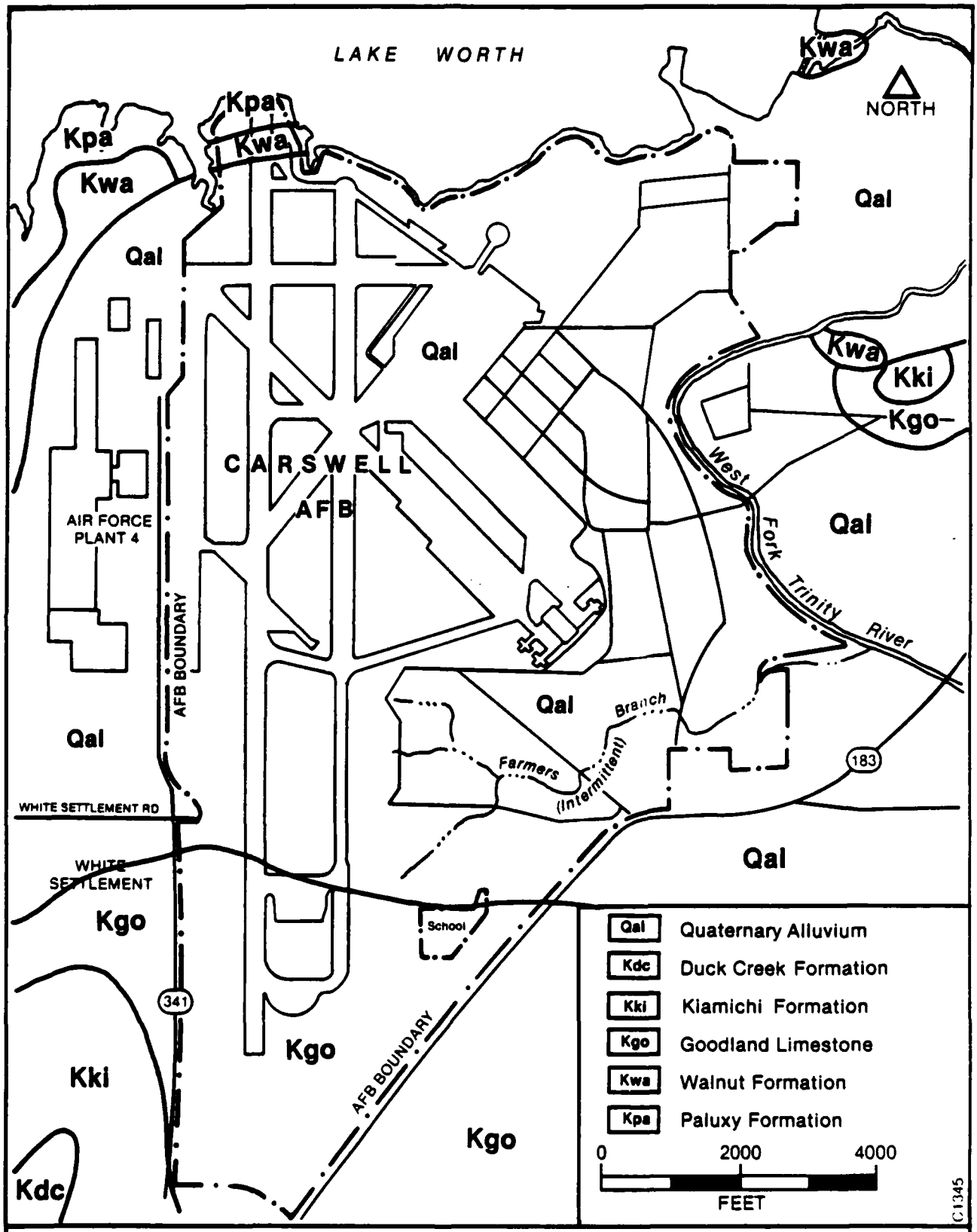

Figure 2-4. Geologic Map of Carswell AFB, Texas.

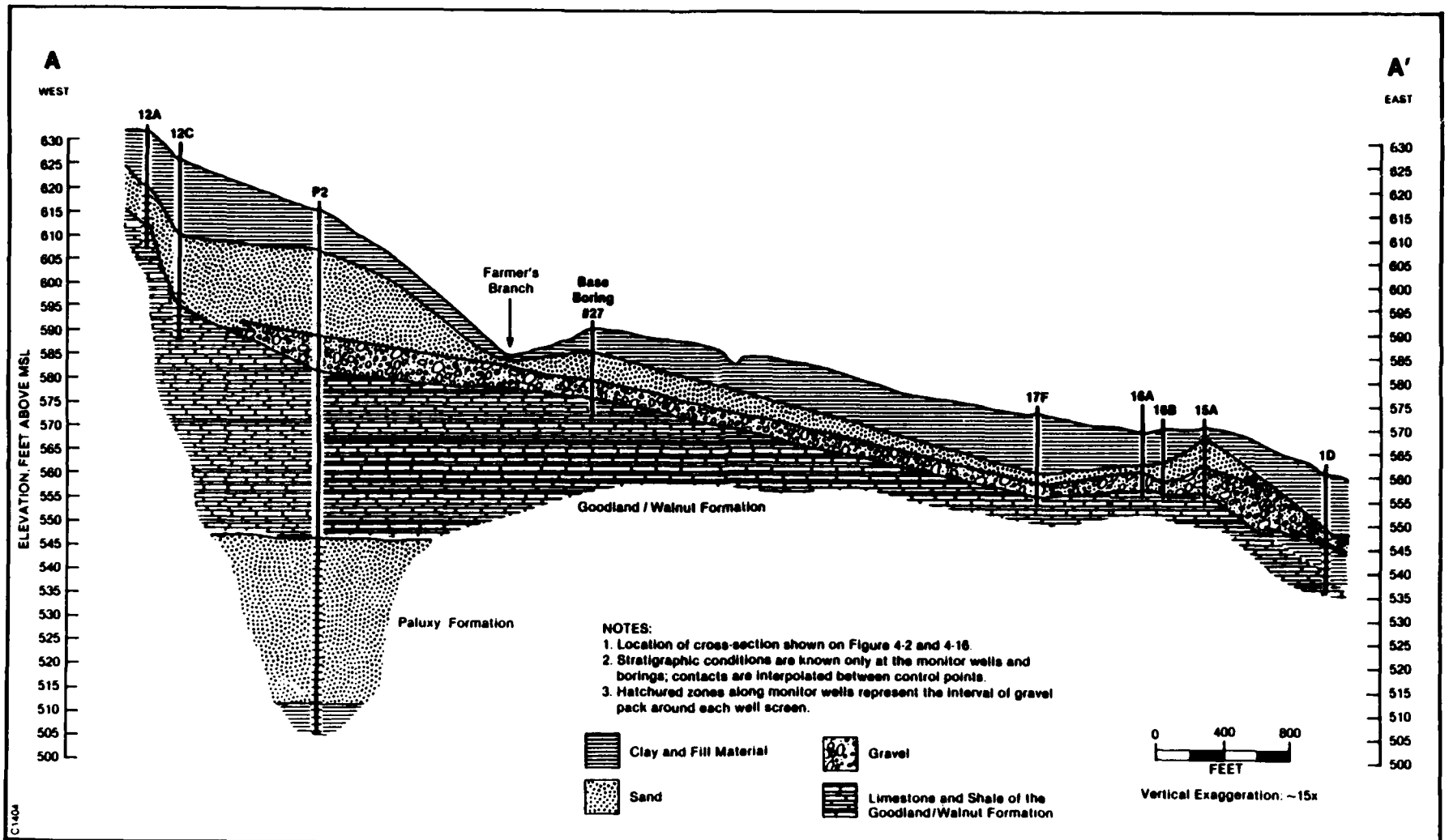

Figure 2-5. Geologic Cross-Section A-A', Carswell AFB, Texas.

Hydrogeology

On the basis of their water-bearing properties, the geologic units at Carswell AFB may be divided into the following five hydrogeologic units, listed from most shallow to deepest: 1) an upper perched-water zone occurring in the alluvial terrace deposits left by the Trinity River; 2) an aquitard of predominantly dry limestone of the Goodland and Walnut Formations; 3) an aquifer in the Paluxy sand; 4) an aquitard of relatively impermeable limestone in the Glen Rose Formation; and 5) a major aquifer in the sandstone of the Twin Mountains Formation. Each of these units is examined in more detail below.

Upper Zone - Ground water occurs within the coarse sand and gravels deposited by the Trinity River, but these deposits are usually limited in areal extent and isolated by surrounding low-permeability clays and silts. Recharge to the water-bearing deposits is local, from rainfall and infiltration from stream channels and drainage ditches. Water flow in the alluvium is basically eastward, toward the West Fork of the Trinity River.

In parts of Tarrant County, generally close to the Trinity river, water in the alluvium is developed for irrigation and residential use. The community of River Oaks, immediately east of Carswell AFB, had supply wells that developed water from the alluvial deposits at a location near the USAF Hospital. The wells were abandoned when Carswell AFB purchased the property for hospital construction. For the most part, ground water is not economical to develop from the alluvium due to the water's limited distribution and susceptibility to surface/stormwater pollution.

Goodland/Walnut Aquitard - The perched water present in the alluvium is separated from the aquifers below by the low permeability limestones and shales of the Goodland Limestone and Walnut Formation. The aquitard is composed of moist clay and shale layers interbedded with dry limestone beds. Though primarily dry, drillers in the area report that small amounts of water enter the borehole while drilling through the Walnut Formation, suggesting that ground water may move through the Walnut along bedding planes (Hargis and

Associates, Inc., 1984). The thickness of the Goodland/Walnut aquitard is approximately 25 feet or greater beneath most of Carswell AFB. However, the top of the aquitard is an erosional surface and weathering may have reduced the thickness of the limestone in isolated areas. A soil boring at AF Plant 4, across the runway to the west from Carswell AFB, revealed that the Goodland Limestone had been completely eroded and only three feet of the Walnut Formation remained (Hargis and Associates, Inc., 1984). It is also reported that the upper zone and Paluxy Formation are in contact at the eastern boundary of AF Plant 4, where both the Goodland and Walnut Formations have been removed by erosion (Hargis and Associates, 1985). In areas of similarly extensive erosion, water in the upper zone could come in contact with water in the Paluxy aquifer.

Paluxy Aquifer - The Paluxy aquifer is the most shallow aquifer occurring beneath Carswell AFB. The aquifer's area extent is shown in Figure 2-6. In the base area, water in the Paluxy would naturally occur under confined conditions beneath the Goodland/Walnut aquitard (except where the aquitard is missing due to erosion, as discussed above). However, extensive pumping in the Fort Worth area has lowered the Paluxy potentiometric surface below the top of the formation, resulting in unconfined conditions beneath the base. The Paluxy Formation is divided into upper and lower sand members and the aquifer is likewise divided into upper and lower aquifers. The upper sand is fine-grained and shaley and the lower sand is coarser; therefore, most wells are completed in the lower section.

Recharge to the Paluxy aquifer occurs where the formation outcrops west of Carswell AFB. The Paluxy also outcrops north of the base in the bed of Lake Worth. The lake represents a significant recharge point for the aquifer and creates a potentiometric high in its vicinity. Regional ground-water flow within the Paluxy is eastward, in the direction of the regional dip. At Carswell AFB, ground-water flow is influenced by the Lake Worth potentiometric high and by a potentiometric low created by the ground-water withdrawals of the community of White Settlement, resulting in a more southeasterly flow direction.

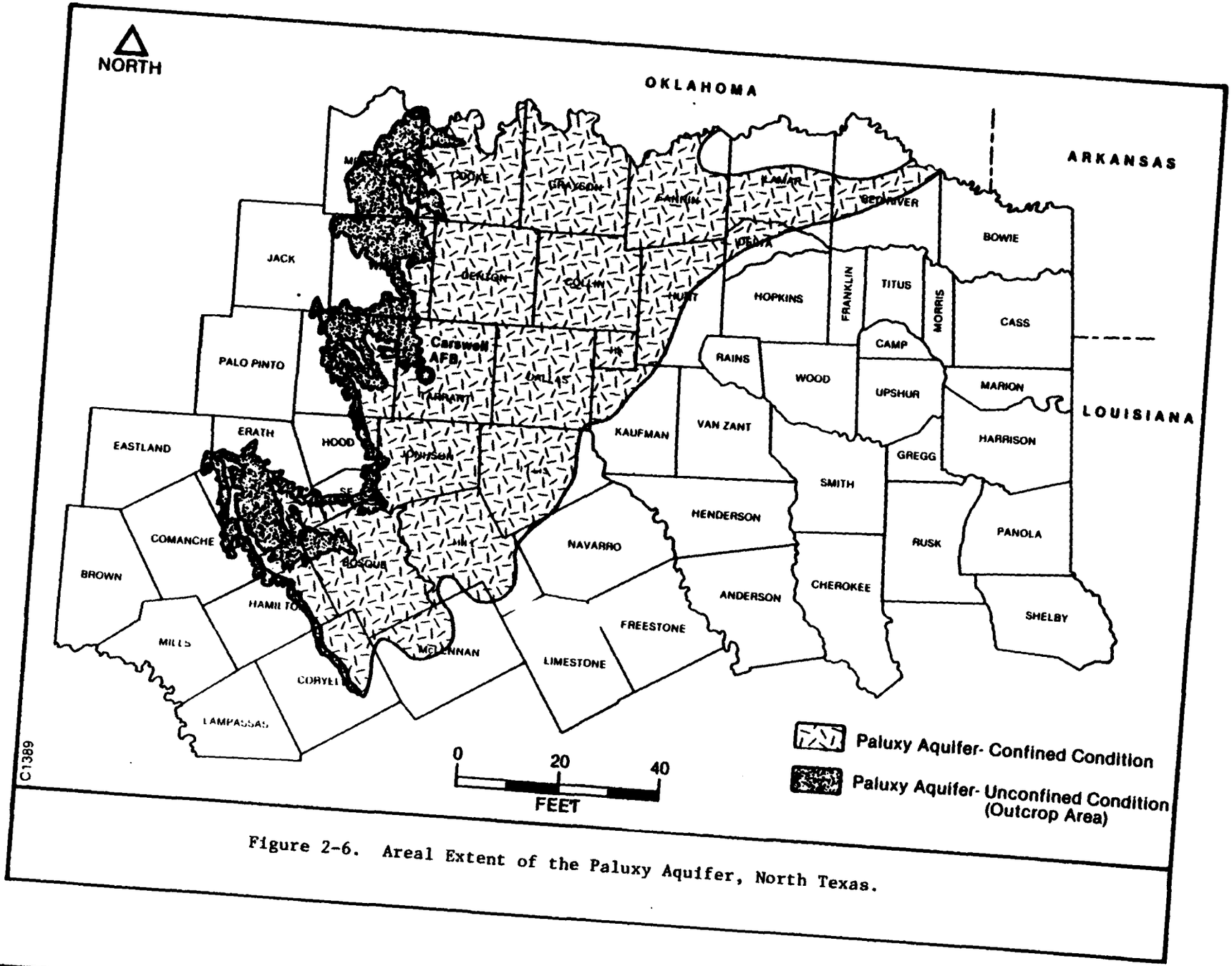

Figure 2-6. Areal Extent of the Paluxy Aquifer, North Texas.

The Paluxy aquifer is an important source of potable ground water in the Fort Worth area. Communities surrounding Carswell AFB, especially White Settlement, develop municipal water supplies from the Paluxy, as well as from the deeper Twin Mountains aquifer. As a result of its extensive use as a water supply, water levels in the Paluxy aquifer have declined significantly over the years. Water levels in the immediate Carswell AFB vicinity have not decreased as much as in the Fort Worth area in general because of the proximity of the Lake Worth recharge area and because the base does not develop water from the Paluxy.

Transmissivities in the Paluxy aquifer range from 1,263 to 13,808 gallons per day per foot (gpd/ft) and average 3,700 gpd/ft. The Paluxy Formation thickness ranges from 140 to 190 feet and averages 160 feet in Tarrant County. The actual water-bearing thickness in the Carswell AFB area probably approximates the formation thickness, but the aquifer is separated into two distinct water-bearing zones. In the vicinity of Carswell AFB, permeabilities range from 13 to 140 gpd/ft^2 (based on an approximate thickness for the aquifer of 100 ft.) Well yields within the Paluxy aquifer range from 10 to 480 gallons per minute (gpm) and average approximately 100 gpm.

Water quality in the Paluxy aquifer is generally good and is satisfactory for potable use. The range of chemical constitutents occurring within Paluxy water is given in Table 2-3.

Glen Rose Aquitard - Below the Paluxy Aquifer are the fine-grained limestone, shale, marl, and sandstone beds of the Glen Rose Formation. The thickness of the formation varies from 250 to 450 feet. Though the sands in the Glen Rose Formation yield small supplies to wells in Fort Worth and western Tarrant County, the relatively impermeable limestone is an aquitard restricting water movement between the Paluxy aquifer above and the Twin Mountains aquifer below.

RADIAN

TABLE 2-3. RANGE OF CONSTITUENTS IN GROUND WATER FROM SELECTED WELLS IN THE PALUXY FORMATION, TARRANT COUNTY

Constituent or Property	Concentration
Bicarbonate (HCO_3)	177-689
Boron (B)	0.1-0.6
Calcium (Ca)	0-120
Chloride (CL)	5-117
Fluoride (F)	0-4.5
Iron (Fe)	0-9.9
Magnesium(Mg)	0-43
Nitrate (NO_3)	0-10.0
Silica (SiO_2)	1-30
Sodium (Na)	11-740
Sulfate (SO_4)	6-1,080
Dissolved Solids	264-2,176
Total Hardness ($CaCO_3$)	2-401
Percent Sodium (%)	7.1-99.5
pH	7.1-9.2
Sodium-Absorption Ratio (SAR)	0.2-68.8
Residual Sodium Carbonate (RSC)	0-10.0
Specific Conductance (umhos at 25°C)	427-3,193

NOTE: Analyses given are in milligrams per liter except percent sodium, specific conductance, pH, SAR, and RSC.

SOURCE: Texas Department of Water Resources, 1982.

Twin Mountains Aquifer - The Twin Mountains Formation is the oldest formation used for water supply in the Carswell AFB area. The formation consists of a basal conglomerate of chert and quartz, grading upward into coarse- to fine-grained sand interbedded with shale. The thickness of the formation varies between 250 and 430 feet.

Recharge to the Twin Mountains aquifer occurs west of Carswell AFB, where the formation crops out. Water movement is eastward in the downdip direction. Like water in the Paluxy aquifer, Twin Mountains water occurs under water-table conditions in the recharge area and becomes confined as it moves downdip.

The Twin Mountains aquifer is the principal aquifer in Tarrant County. The formation yields large water supplies for municipal and industrial purposes. Transmissivities in the Twin Mountains aquifer range from 1,950 to 29,700 gpd/ft and average 8,450 gpd/ft in Tarrant County. Permeabilities range from 8 to 165 gpd/ft^2 and average 68 gpd/ft^2 in Tarrant County.

Ground-water withdrawals from the Twin Mountains aquifer, primarily for municipal water supply, have resulted in declining water levels. Between 1955 and 1976, the potentiometric surface of the aquifer dropped approximately 250 feet.

Water quality in the Twin Mountains aquifer is suitable for potable use throughout the Fort Worth area. Water in the upper sands east of Fort Worth may be too mineralized for human consumption.

2.4 Site Descriptions

Phase I studies for the Carswell AFB Installation Restoration Program were completed by CH2M Hill in February 1984. The purpose of the Phase I study was to conduct a records search for the identification of past waste management activities which may have caused ground-water contamination and the migration of contaminants off-base.

Twenty-two disposal and spill sites were identified at Carswell AFB and one off-base facility by the Phase I investigation. The potential environmental consequence of 14 sites were evaluated using the U.S. Air Force Hazard Assessment Rating Methodology (HARM). This system took into account such factors as the receptors of the contamination, the nature of the waste, potential pathways for contaminant migration, and efforts to contain contamination.

Eleven individual sites at Carswell AFB and one off-base facility were identified as requiring Phase II monitoring. The locations of these sites are shown on Figure 1-2. They are listed, in priority order according to their HARM rating, on Table 2-4. The general features of each site listed are discussed below in order of priority.

2.4.1 Site 13, Flightline Drainage Ditch

This site consists of a ditch directly east of the main aircraft washrack and Hangars 1048 and 1049. The ditch is unlined from its beginning just east of Haile Drive to its intersection with the POL tank farm, where the ditch becomes concrete-lined. In addition to receiving normal storm drainage, the flightline drainage ditch receives discharge from the aircraft washracks (PD-680, a cleaning solvent, and aircraft soap) and from the Fuel Systems Shop (JP-4). Washrack wastes are discharged to an oil/water separator adjacent to the ditch; however, a valve in the drain line from the washracks to the separator can be opened, allowing discharge directly into the flightline drainage ditch. Jet fuel drained from fuel tanks in the Fuel Systems Shop was formerly piped to an oil/water separator. A rupture in the pipe five years ago has allowed JP-4 to enter a stormwater culvert that leads to the flightline drainage ditch. Base engineers have plans to correct the rupture.

Field activities during Phase I identified aircraft soap entering the flightline drainage ditch, petroleum products on the surface of water in the ditch, and the presence of a dark zone of fuel or oil saturation along the banks of the ditch.

TABLE 2-4. PHASE I PRIORITIZED SITE LISTING, CARSWELL AFB, TEXAS

<u>On-Base Facilities</u>:
1. Flightline Drainage Ditch, Site 13.
2. Fire Department Training Area 2, Site 12
3. POL Tank Farm, Site 17
4. Waste Burial Area, Site 10
5. Unnamed Stream, Site 16
6. Entomology Dry Well, Site 15
7. Landfill 1, Site 1
8. Landfill 4, Site 4
9. Landfill 5, Site 5
10. Fire Department Training Area 1, Site 11
11. Landfill 3, Site 3
<u>Off-base facilities</u>:
Inspection Shops at the Weapons Storage Area

2.4.2 Site 12, Fire Department Training Area 2

Site 12 is located between the north-south taxiway and the radar facility. This site has been used as a fire department training area since 1963. The fire ring is gravel-lined with a low earthern berm around its perimeter. Waste oils and recovered fuels, and possibly waste solvents, have been the primary materials burned during fire training exercises.

Clean or contaminated fuels are stored in an on-site 8,500-gallon aboveground tank before they are delivered to the fire ring via a pump and an underground network of pipes. Also at Site 12 is a 9,500-gallon underground tank used for the storage of waste oils and solvents from the flightline shops. The waste in the underground tank is usually removed by off-base contractors; however, Phase I interviews revealed that the contents of the underground tank have been used for training exercises in the past.

Unburned JP-4 was present on the ground during the Phase I field investigaton, and a breach in the earthern berm surrounding the fire pit was noted during the Phase I work, during the Radian Presurvey of the site, and during the Phase II investigation.

2.4.3 Site 17, POL Tank Farm

The POL Tank Farm is located along Knight's Lake Road, near the Carswell AFB main gate. Currently, the site consists of three aboveground tanks with a fourth under construction. Three additional tanks were formerly located at this site, but have been removed. An underground French drain system east of the tank farm may have been installed to collect fuel in the ground at the POL Tank Farm; however, the Radian Presurvey report identified the possibility that the drain was installed at the site of a former gasoline station.

During the early 1960's, fuels were discovered in the ground in the POL Tank Farm area and downgradient of the tank farm. The cause of the contamination was attributed to leaking underground POL pipes. The pipes were located and replaced. No additional loss of fuel is suspected to have occurred in this area since 1965, though fuel is still suspected to be in the ground in the POL tank farm area.

2.4.4 Site 10, Waste Burial Area

The Waste Burial Area is located immediately north of White Settlement Road where the road deadends near the north-south taxiway. The site was used for the burial of wastes during the 1960's, including drums of cleaning solvents, leaded sludge, and possibly ordnance materials (which may have been buried live). The wastes were reportedly buried in an impermeable clay bed. The site is identified on the surface by signs reporting the presence of tetraethyl lead.

2.4.5 Site 16, Unnamed Stream

The Unnamed Stream is a small tributary of Farmers Branch that emerges from an oil/water separator. The separator and the stream are located south of the new communications building (Bldg. No. 1337), near the confluence of Farmers Branch and the West Fork of the Trinity River. The oil/water separator is connected to a French underdrain system which was reportedly built in 1965. The drain may have been built to capture POL leaking from the POL Tank Farm, or it may have been used to collect leaking fuels from a former base gasoline station (now removed) that was located north of the stream.

The Unnamed Stream receives perennial flow from ground water entering the French drain and separator. The separator has not been routinely cleaned for some years and is believed to contain hydrocarbon contamination. Overflow from the separator is apparently discharging hydrocarbons and high levels of iron into the Unnamed Stream. The Phase I study reported that the stream had a petroleum odor, an oil sheen, and extensive growths of reddish

brown iron-reducing bacteria. Analyses completed on the stream by the base Bioenvironmental Engineer during the summer of 1983 revealed trace levels of trichloroethylene.

2.4.6 Site 15, Entomology Dry Well

Site 15 was located immediately west of the entomology shed (Bldg. 1338). The entomology shed has been removed and Site 15 now occupies a graded, partially paved lot in the vicinity of the new communications building (Bldg. No. 1337). Building No. 1338 was used for the storage and mixing of insecticides and for the storage and cleaning of spray equipment. Insecticides known to have been stored in Bldg. 1338 include malathion, diazinon, dursban, and chlordane. The Entomology Dry Well was used for the disposal of insecticide rinsate between 1965 and 1981. Chlordane has been reported in samples taken from the dry well; however, the Phase I study could not substantiate the report.

2.4.7 Site 1, Landfill 1

Site 1 is located next to the West Fork of the Trinity River, beneath the present DRMO storage yard. Landfill 1 is reported to be the original base landfill, operated during the 1940's. There is no information available concerning past waste disposal practices at this site because of the length of time since its closing.

2.4.8 Site 4, Landfill 4

Site 4 is located at the radar station compound east of the north-south taxiway. This landill was operated from approximately 1956 to 1975 and was the main base landfill during most of Carswell AFB's history. All base refuse was burned and buried here in at least six large pits, approximately 12 feet deep. Materials suspected of being hazardous were reportedly disposed at this site, including drums of waste liquids, partially full paint cans, and

cadmium batteries. The Phase I study also located records indicating that the routine disposal of waste paints, thinners, strippers, oil-containing adsorbent materials, PD-680, and oils may have been practiced at this location.

2.4.9 Site 5, Landfill 5

Landfill 5 is located northwest of Landfill 4 and between Fire Department Training Areas 1 and 2. Just to the west of Landfill 5 is a current landfill site apparently used for construction rubble. Landfill 5 is located next to a small tributary to Farmers Branch and was constructed by building a clay berm next to the creek and then filling in the area behind the berm. The landfill received all types of flightline wastes and refuse, and was regularly burned prior to covering.

2.4.10 Site 11, Fire Department Training Area 1

Site 11 is located north of Landfill 5, across a small tributary to Farmers Branch. This training area was probably the primary fire pit prior to 1963. The pit was reportedly gravel-lined and surrounded by a low concrete curb. Fire training exercises were reported to have been conducted several times each month. Waste oils and contaminated fuels were the primary flammable liquids used in the exercises, though small quantities of solvents are also suspected of having been burned.

2.4.11 Site 3, Landfill 3

Landfill 3 is located under the present runway, immediately south of the culvert that carries Farmers Branch from AF Plant 4 to the east side of the runway. The landfill occupied a ravine that was present when the runway ended north of Farmers Branch. Landfill 3 was used between 1950 and 1952 for the burial of all types of waste, though construction rubble was the primary constituent.

2.4.12 Weapons Storage Area (WSA)

The Weapons Storage Area (WSA) is the only off-base facility included in the Phase II study. The area is located approximately eleven (11) miles west of Carswell AFB, north of White Settlement Road. The facility is on 247 acres of fee-owned land and is surrounded by an additional 264 acres of easements.

The WSA is located in the Cross Timbers and Prairies Region (CH_2M-Hill, 1984), in the outcrop area for the Fredericksburg and Washita Groups. The underlying Paluxy sand is also exposed in some areas. The land in the WSA area consists of unimproved pasture heavily grazed by beef cattle and of natural oak woodlands populated by white-tail deer and coyotes.

The WSA is located between two forks of Live Oak Creek, which flows east to its discharge point at Lake Worth. Elevations in the area range from 720 to 800 feet msl. Potable water at the WSA is supplied by two wells (one is standby), 218 feet deep. These wells probably produce from the Paluxy Aquifer.

The WSA facility was built in 1956. The site includes two munitions inspection shops, 16 ordnance storage buildings (including 11 igloos), one entry-control building, an emergency power plant, an Explosive Ordnance Disposal range, a radioactive waste disposal facility, a water storage tank, and two water wells. Areas considered by the Phase I investigation include the inspection shops, the radioactive waste disposal facility, an open dump, the EOD range, and a spent engine-cartridge pit.

The inspection shop site, specifically the ground behind Building 8503, was found by the Phase I study to be the site of occasional dumping of waste cleaners and solvents. The substances are suspected to have been paint thinners and trichloroethylene. An estimated 5 to 10 gallons of waste a year were disposed on the ground behind Building 8503.

The radioactive waste disposal area consists of three dry waste wells (18 feet deep) constructed of 12-inch diameter cast iron pipes encased in 2-1/4 inches of grout. The wells were used from 1957 to 1969 to dispose of radioactive and non-radioactive wastes. The Phase I investigation reported that the wells contain plutonium contaminated swipe samples, rubber gloves paper bags, and uranium oxide. The wells were permanently capped in 1969 and the site is fenced with radiation caution signs. Routine radiation measurement at the site have been negative.

The open dump has apparently received only non-hazardous debris, such as wood, metal, paper, etc. The EOD range contains buried spent ordnance scrap, but was not considered an environmental threat. The spent engine-cartridge burial pit contains primarly rubber material with minimal explosive residues.

3.0 FIELD PROGRAM

Radian performed various field activities at Carswell Air Force Base as part of the IRP Phase II Stage 1 investigation. The activities consisted of geophysical surveys in the vicinity of waste disposal and spill sites, installation of twenty-three shallow (upper zone) ground-water monitor wells, installation of two monitor wells in the Paluxy aquifer, drilling of eleven soil borings, completion of hand augered borings at several locations, and the collection of ground-water, surface-water, soil, and sediment samples. These activities were recommended in the Carswell AFB IRP Phase IIA report (Radian, 1984). The locations of the field investigations are shown in Figure 3-1. The period of performance of the field activities was December 1984 through March 1985.

3.1 Field Techniques

The following paragraphs contain descriptions of the various field techniques used in the Carswell AFB Phase II Stage 1 investigation. These techniques included geophysical surveys, hollow-stem auger and rotary drilling, monitor well installation, hand augering, and soil and water sampling.

3.1.1 Geophysical Surveys

Geophysical surveys were performed in order to accurately define the vertical and lateral extent of waste-disposal activities, provide a clearer picture of the subsurface conditions around the sites, and investigate the potential for buried objects at several locations. All survey grids were laid out using a compass and measuring chain. Stations were marked with labelled pin flags or spray paint in areas where asphalt or hard ground discouraged the use of pin flags. Several geophysical techniques were used during the investigations: earth resistivity by direct current Schlumberger soundings (vertical electrical soundings - VES), magnetic and magnetic gradient surveying, and fixed frequency electromagnetic profiling (EMP) conductivity surveys at three different effective depths (10, 20, 50 feet) of exploration. The Earth Technology Corporation of Golden, Colorado, performed the geophysical surveys at Carswell AFB.

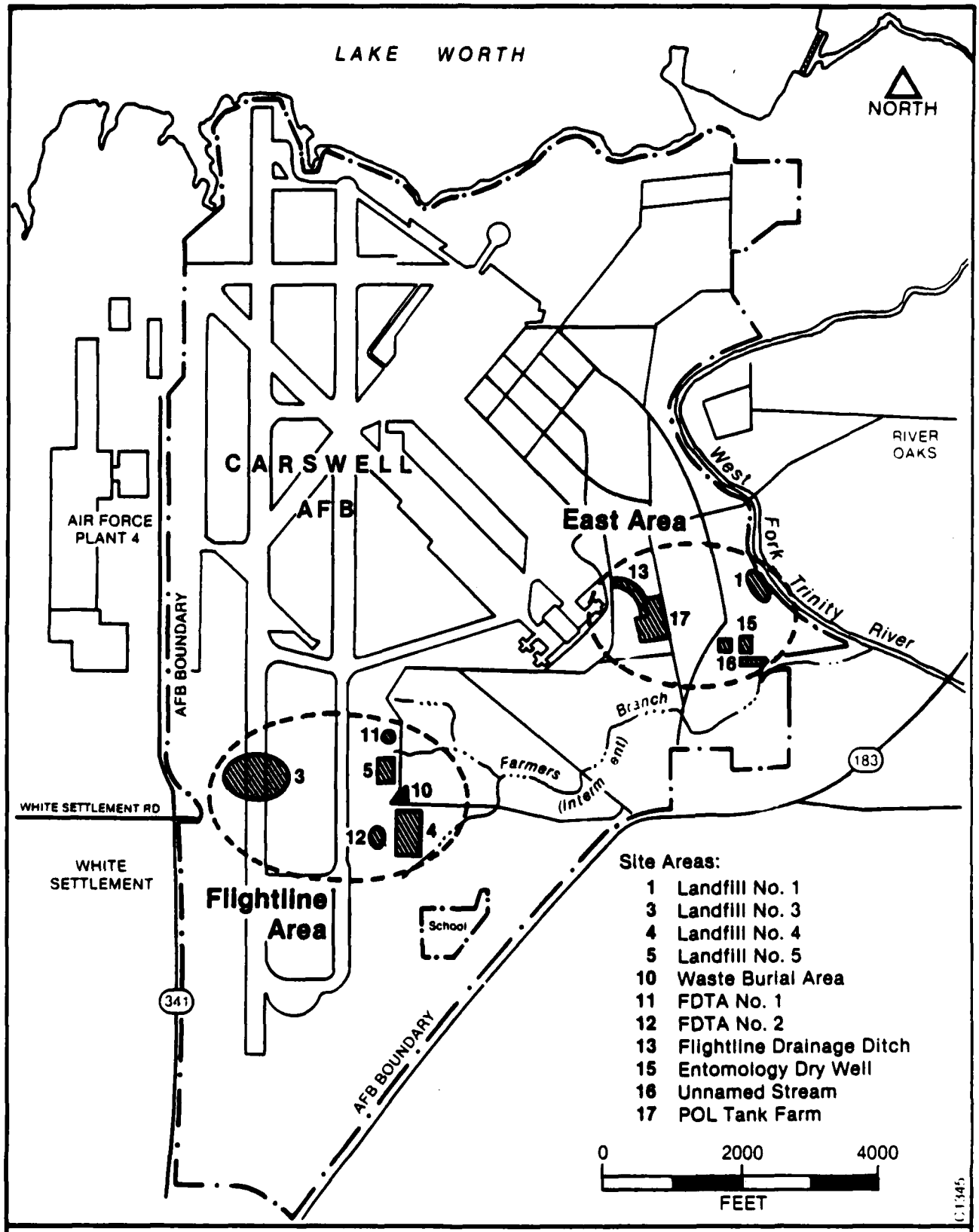

Figure 3-1. Areas of Investigation, Carswell AFB, Texas.

Electrical Resistivity

The Bison Model 2350 Earth Resistivity meter was utilized for the VES measurements. Current electrode separations used were (in meters): 1, 2, 3, 4, 6, 10, 14, 20, 30, 40, and 50. Due to variable ground conductivity, potential electrode separations varied slightly from site to site. The sounding data was processed using the ABEM VES iteration process to obtain a best fit curve and plotted logarithmically as resistivity in ohm-meters versus half the current electrode separation in meters. The plot also includes the layered earth model giving the best match. At most VES sites, orthogonal electrode arrays were used. The reason for this is to test for distortions of the data due to lateral inhomogeneities in the ground.

Electromagnetic Surveys

EMP surveys were conducted at Sites 1, 3, 4, 5, 10, 11, and 12 using two devices: the Geonics EM31 and the Geonics EM34-3 ground conductivity sensors. Both ground conductivity sensors are designed for rapidly obtaining data over large areas. The meters employ magnetic dipoles or magnetic induction loops for transmission and reception of low-frequency electromagnetic waves. The effective depth sampled by the EM31 is 6 meters; the depth sampled by the EM34-3 depends on the coil separation and orientation, applied frequency, and to some extent on the conductivity profile of the subsurface. The techniques and conditions at Carswell AFB resulted in an effective sampling depth of 50 feet with the EM34-3. The data are in units of millimhos/meter.

Magnetometer Surveys

Magnetometer surveys were accomplished using an EDA PPM500 proton magnetometer. The use of the magnetometer was based on the fact that overburden at Carswell has a low magnetic susceptibility; the buried objects were believed to contain a significant amount of iron that would create a noticeable magnetic anomaly. Readings of the total field and magnetic gradient were taken at each location. The units for these readings are gammas and gammas per 1/2 meter, respectively.

3.1.2 Drilling Techniques

Drilling at Carswell AFB was accomplished using a hollow-stem auger rig for the upper zone monitor wells and soil borings and a rotary drilling rig (using both mud and air) for the Paluxy monitor wells. These methods were selected on the basis of the anticipated depth of completion, need for water-level observations, and expected geologic conditions. The following paragraphs provide descriptions of the procedures used for the drilling activities.

Hollow-Stem Augering

A hollow-stem auger drilling rig, the CME-75, was used to perform shallow soil borings and installation of the upper zone monitor wells. The hollow-stem method allowed for an accurate examination of soil conditions, identification of the position of the water table, and recovery of soil samples. The holes were drilled dry; no drilling fluids or additives were used. Samples of soil were collected with a split-spoon sampler, a hollow tube driven in advance of the auger at 5-foot intervals (ASTM D-1586). The samples were recovered at the surface, described in terms of lithology and moisture, and retained. Selected samples were frozen and shipped to Radian's laboratory for chemical analysis. Parameters for analysis are listed in Table 3-1.

Air Rotary Drilling

The rotary drilling was performed with a Gardner-Denver 1500 CD truck-mounted rig. A 6-inch bit was used to advance a pilot borehole through the upper zone alluvial material and to a depth of at least 5 feet into the underlying Goodland Limestone. The borehole was then reamed to a diameter of 14-inches. A 10-inch diameter steel casing was installed to the full depth of the borehole and the annular space grouted. Upon achieving a positive seal, the borehole was advanced using a 6-inch diameter bit to the final depth at the shale unit dividing the upper and lower Paluxy Formation. Bentonite

TABLE 3-1. ANALYTICAL SCHEDULE FOR SOIL SAMPLES, CARSWELL AFB, TEXAS

Site	Parameters				
	Oil & Grease	Pesticides	Phenols	Heavy Metals	Purgeable Organics
Landfill 1 (1)	X	X	X	X	X
Landfill 4 (4)			X	X	
Landfill 5 (5)	X	X	X	X	X
Waste Burial Area (10)	X				X
Fire Training Area 1 (11)	X	X	X	X	X
Fire Training Area 2 (12)	X		X	X	X
Entomology Building (15)		X			
POL Area (17)	X				

drilling fluid was used while drilling in the Paluxy owing to borehole instability during air rotary operations. The well was then installed in the borehole as described in the text below. As the borehole was advanced, the cuttings discharged at the surface were examined for lithology, moisture, and other features useful in describing the geologic section. Drilling conditions, such as relative rate and ease of penetration, were noted by the driller. Water encountered during drilling was noted with respect to depth of occurrence and rate of production. If needed, drilling was suspended temporarily to allow for recovery of water in the borehole.

3.1.3 Monitor Well Installation

The following paragraphs describe the rationale for selecting locations of the ground-water monitor wells and the techniques used in their construction.

3.1.3.1 Monitor Well Locations

Upper Zone

Monitor wells installed as part of the Phase II investigation at Carswell AFB are centered in two areas at the Base (Figure 3-1). The flightline area wells (Sites 4, 5, 10, 11, 12) shown in Figures 3-2 and 3-3 were located in order to define upgradient and downgradient conditions relative to the waste-disposal features of the area. In the absence of ground-water data at the sites, topographic conditions were used to select monitor well locations. Ground-water flow in the upper zone was assumed to be downslope to the Trinity River, so that upgradient wells were located at higher elevations than downgradient wells. For example, wells 12A and 5A provide upgradient data relative to the cluster of sites at the flightline, whereas wells 4A and 10A provide upgradient conditions relative to individual sites, but may not have monitored upgradient conditions relative to all sites. Selection of all well locations was made in order to determine both the impact of waste disposal operations at individual sites as well as the impact of aggregate sites.

The same line of reasoning was followed for the location of the east area wells and boreholes in the vicinity of the main gate and DPDO yard (Figures 3-4, 3-5, and 3-6). At Site 17, the upgradient borings were located in such a way as to minimize the opportunity for any effect of off-site contamination. For sites 15 and 16, it was very difficult to assure that the upgradient wells in these locations would not be influenced by upslope activities occurring at the POL storage tank and fuel transfer operations. In these settings, well 15A and boring 16A provide upgradient data for the individual sites but probably do not represent conditions unaffected by the POL activities. However, boring 17A would probably achieve upgradient status in that no significant waste-disposal actions are known to have occurred upslope from this boring.

All downgradient wells were located so as to intercept probable ground-water flowlines extending through the sites.

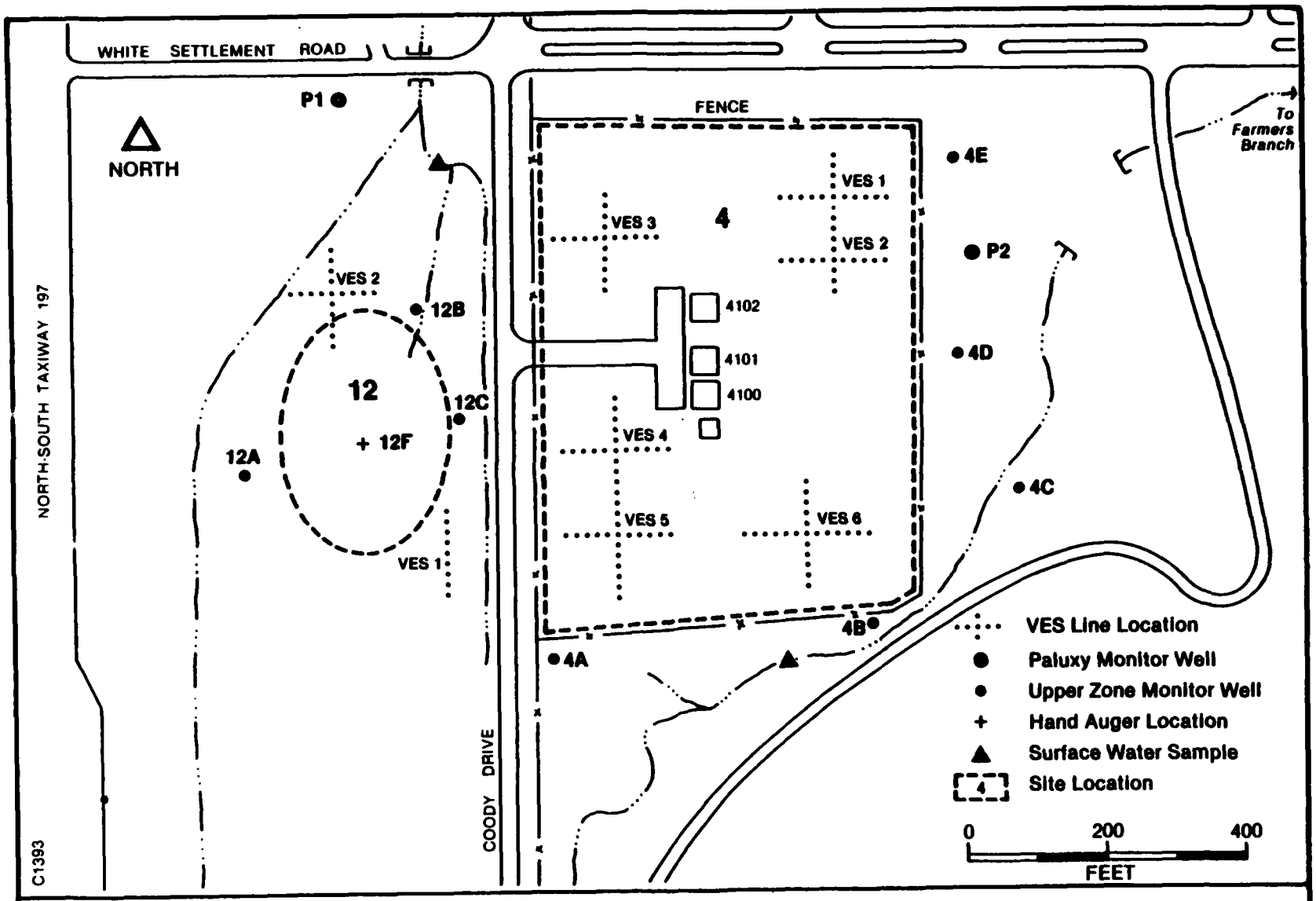

Figure 3-2. Location of Monitoring Points and Geophysical Surveys: Landfill 4 (Site 4) and Fire Department Training Area No. 2 (Site 12), Carswell AFB, Texas.

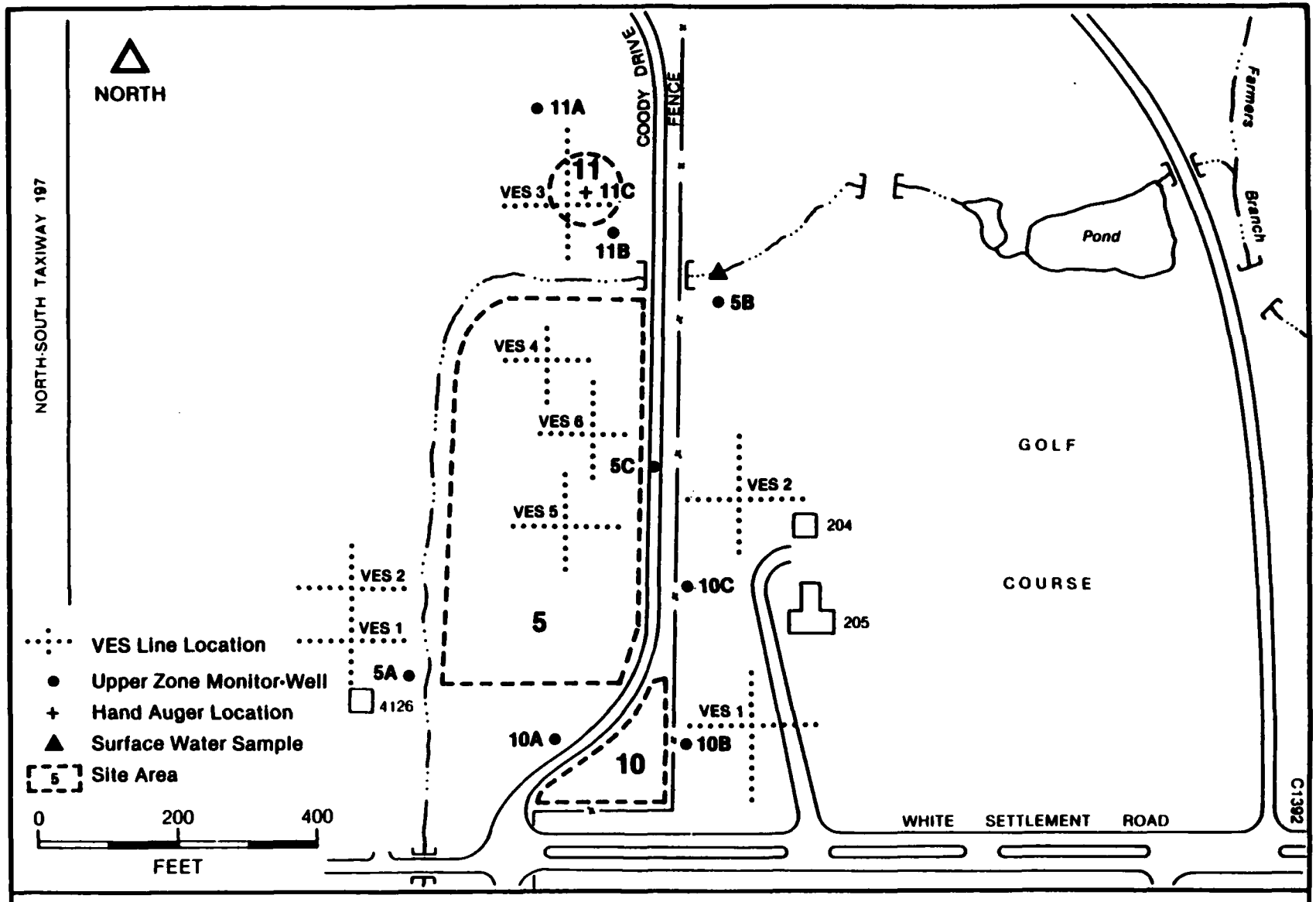

Figure 3-3. Location of Monitoring Points and Geophysical Surveys: Landfill 5 (Site 5), Waste Buried Area (Site 10) and Fire Department Training Area 11 (Site 1), Carswell AFB, Texas.

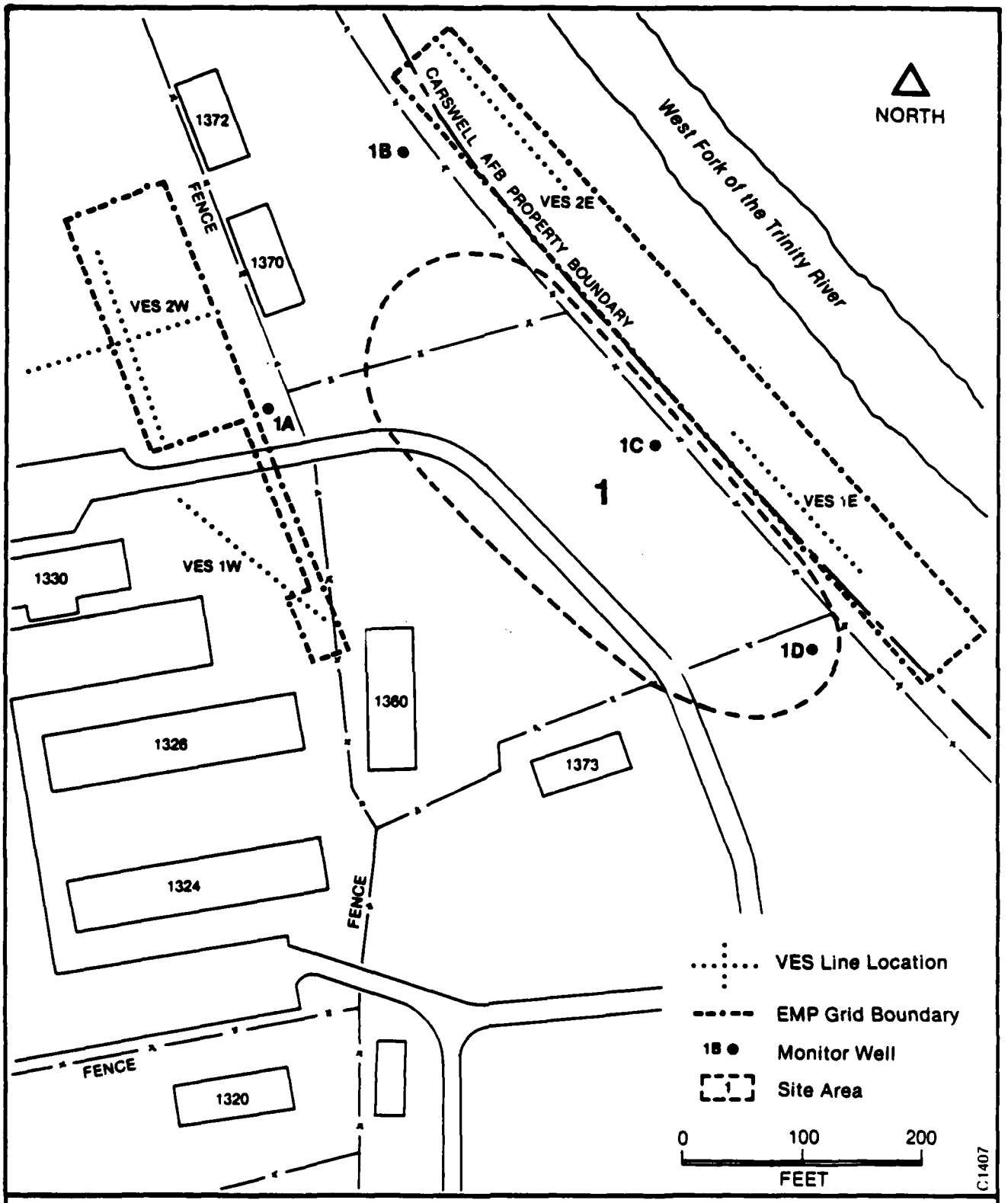

Figure 3-4. Location of Monitor Wells and Geophysical Surveys: Landfill No. 1 (Site 1), Carswell AFB, Texas.

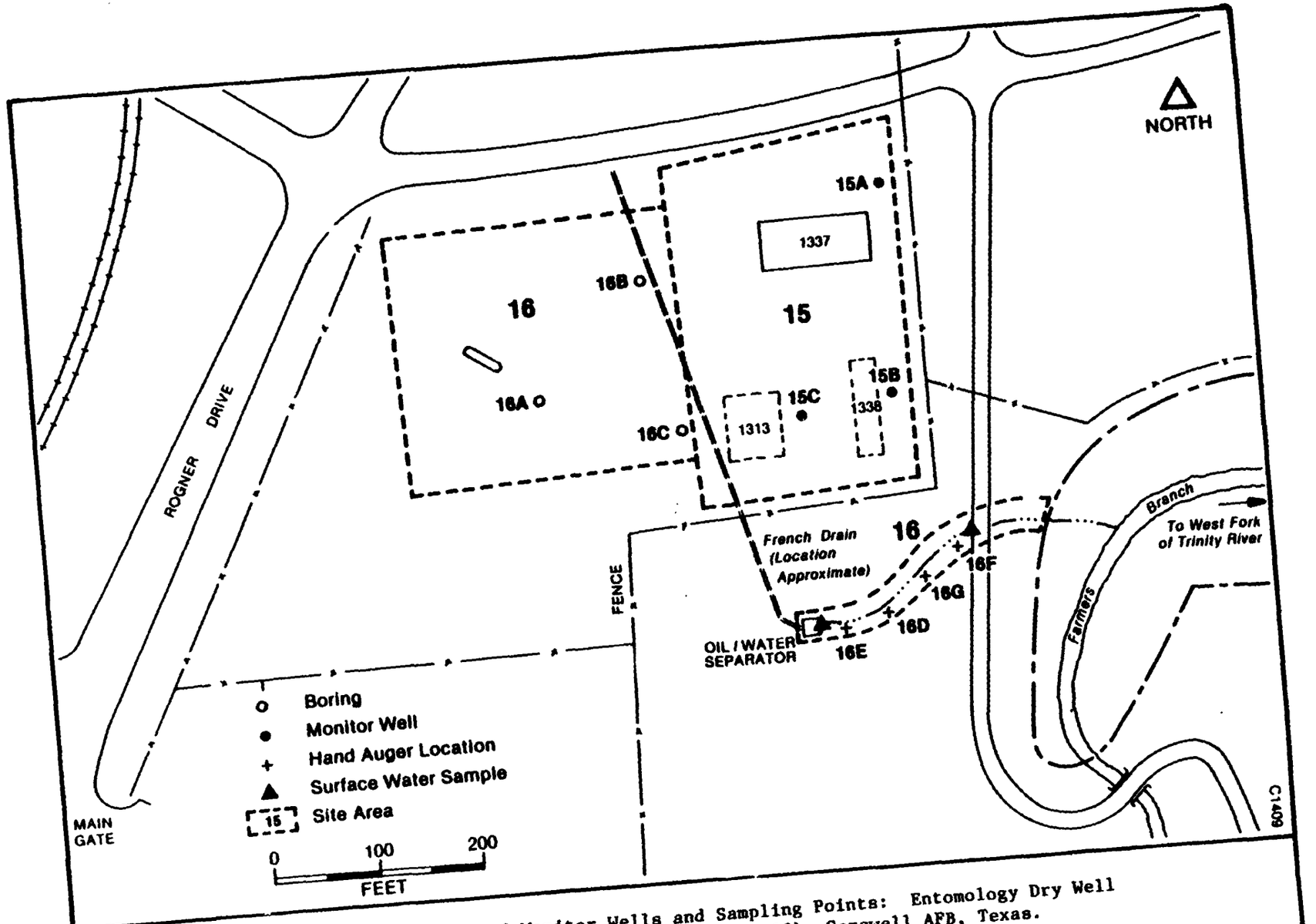

Figure 3-5. Location of Monitor Wells and Sampling Points: Entomology Dry Well (Site 15) and Unnamed Stream (Site 18), Carswell AFB, Texas.

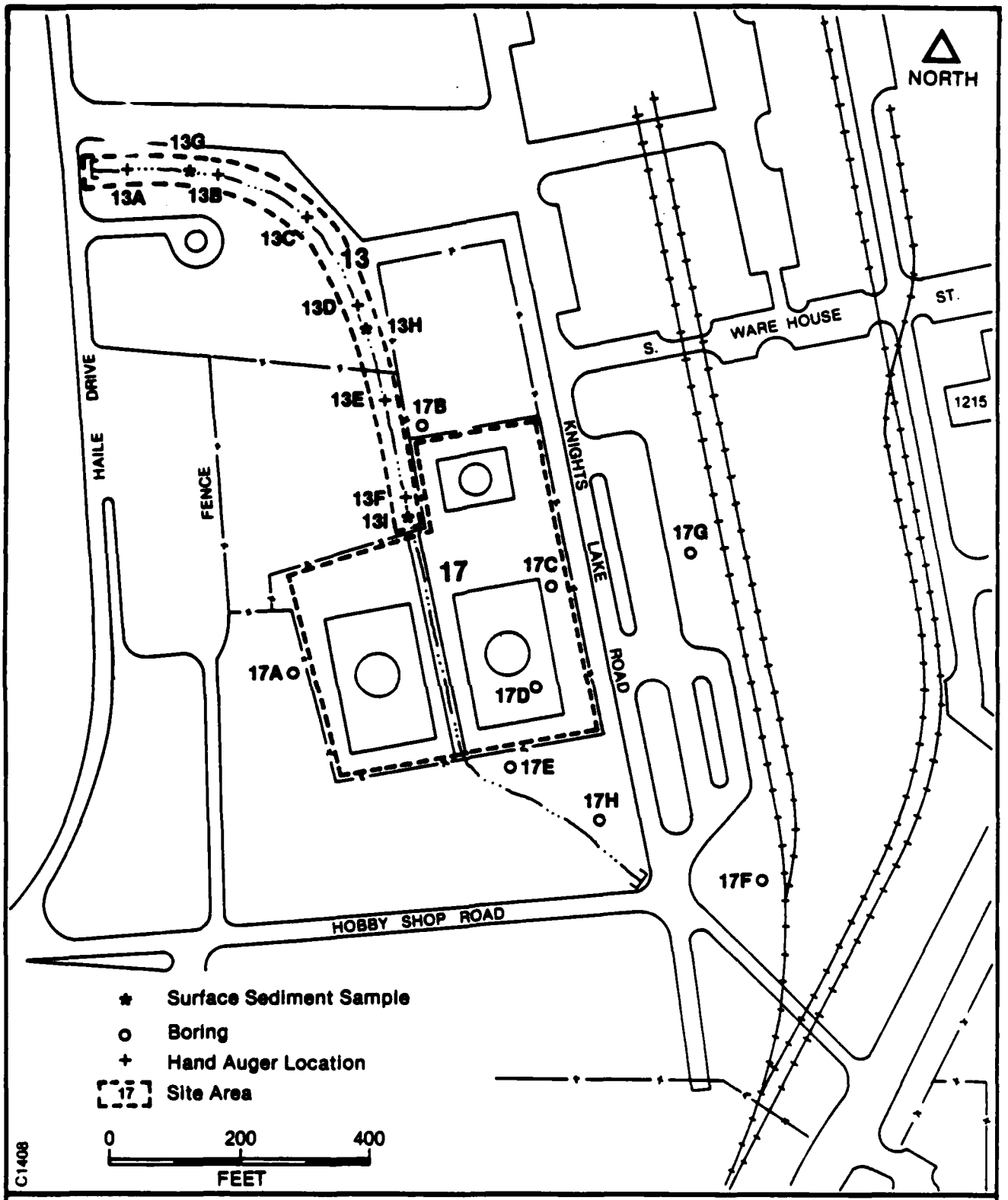

Figure 3-6. Location of Boreholes and Sampling Points: Flightline Drainage Ditch (Site 13) and POL Tank Farm (Site 17), Carswell AFB, Texas.

Paluxy Formation

Two Paluxy Formation wells were installed in the vicinity of the flightline area sites (Figure 3-2). A review of literature suggested that ground-water flow in the Paluxy is to the east; therefore, the wells were aligned so as to intercept ground-water flow both upgradient and downgradient of the disposal areas.

3.1.3.2 Well Installation Methods

Upper Zone

Ground-water monitor wells were installed immediately upon completion of the drilling operations. Usually, the borehole was observed for a period of time, as necessary, to determine the approximate static water level. Monitor well construction specifications, summarized in Table 3-2, were generally consistent with the specifications provided in the Statement of work. Appropriate changes in the specifications were made on a site-by-site basis. The decisions relating to the setting of screen and casing, length of screen, and amount of gravel pack for each well were made on the basis of the observed static water level. If appropriate, the borehole was allowed to remain open overnight; there were no difficulties associated with the integrity of the borehole or caving problems.

The monitor wells were installed in the following way: screen and casing sections were cleaned and assembled on the ground, then lowered carefully into the borehole. As the string of screen and casing were lowered, additional sections of casing were added until the bottom of the screen reached the complete depth of the borehole. Normally, enough casing was attached so as to leave a 2 to 3 foot stick-up at the ground surface. Clean gravel was carefully poured down the annular space until the level of the top of the gravel pack was at least 2 feet above the top of the screen (or as directed by the supervising geologist, see individual well completion logs). Bentonite pellets were added to form a 2-foot thick seal, and if necessary, water from the well was bailed and poured down the annular space to hydrate the bentonite for completion activities that occurred above the water table.

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TABLE 3-2. UPPER ZONE MONITOR WELL CONSTRUTION SPECIFICATIONS FOR CARSWELL AFB, TEXAS

- Casing: 2-inch diameter, flush joint, Schedule 40 PVC.
- Screen: 2-inch diameter, flush joint, Schedule 40 PVC, 0.010-inch mill slot. Normal screen length was 10 feet, adjusted to 5 feet at the discretion of the supervising geologist.
- Gravel pack: Texas Blastsand No. 1A, emplaced from bottom of hole to 2 feet above top of screen.
- Bentonite seal: 2 feet above top of gravel pack.
- Grout: neat cement (Type I Portland cement) grout tremied from the top of the bentonite seal to the land surface.
- Surface completion: the PVC casing was cut off to provide a 2 to 3 foot stickup and solid cap placed on the casing. A 4-inch diameter guard pipe, 6 feet in length, was placed over the exposed casing, and seated in the cement. A locking cap lid was installed on the guard pipe.
- Guard pipes or posts: 3-inch diameter steel posts, 6 feet in length, with a minimum of 2 feet below ground, 3 each installed radially 4 feet from the wellhead.
- After each well was installed, it was developed by hand pumping until a clear stream was produced, or until the supervising geologist determined that development was complete.
- The split-spoon sampler was washed between samples (water, acetone, water) and the drill pipe, bit, and augers cleaned (pressure water wash) between monitor wells.

Neat cement grout was then prepared and tremied from the top of the bentonite seal to the land surface. After completion of grouting, protective 4-inch diameter steel casing with lockable lids was cemented into place at the surface and three steel guard posts were positioned around the well.

The monitor wells were developed by pumping with a hand-operated pump. This technique involved removing water by means of a 1.7-inch diameter pump, usually with the effect of dewatering the well. The water in the casing was alternately purged and allowed to recover; this process generally took several hours. Most of the upper zone wells had very low yields. Water was removed from the well until the sediment content of the water was visibly reduced.

Southwestern Laboratories, of Dallas, Texas, performed the upper zone drilling and monitor well installation work.

Paluxy Formation

After drilling operations were completed, the monitor wells were installed as follows. Screen and casing, consisting of 5-inch diameter Schedule 80 PVC, was installed into the 10-inch borehole. Gravel pack material (Texas Blastsand No. 1A) was placed in the annular space to a level of five feet above the top of the screen. Bentonite pellets were added to form a 2-foot thick seal, and then the annular space was grouted to the surface by the tremie method. The well was developed by bailing until a sediment-free discharge was produced. A 1/3 horsepower stainless steel submersible pump was installed after development. Protective casing, surface electrical connections, and a concrete well pad were placed after the pump was installed.

Underground Resource Management, Inc., of Austin, Texas, conducted the Paluxy drilling and monitor well installation work.

3.1.4 Environmental Sampling

Environmental samples collected as part of the Phase II investigation at Carswell AFB included surface sediment, soil, surface water, and ground water. The following sections provide information on the techniques used in the acquisition of the samples.

3.1.4.1 Sediment Sampling

Samples of sediment were collected at three locations at Site 13, the Flightline Drainage Ditch. The purpose of sediment sampling was to complement data collected as part of the hand augering performed at the ditch. Samples were collected at the surface by gently removing the uppermost sediment from the ditch with a trowel or quart mason jar. Sediment samples were analyzed for oil and grease and EP Toxicity (metals).

3.1.4.2 Soil Sampling

Samples of soil were collected at several locations by using a hand-operated auger. Hand augering was performed at the Flightline Drainage Ditch (Site 13), Unnamed Stream (Site 16), Fire Training Areas 1 and 2 (Sites 11 and 12), and the Weapons Storage Area. The auger, with extensions, was able to retrieve soil samples at a depth of 10 feet below the land surface. The sampling technique involved augering to the desired depth, cleaning the auger with water and acetone, retrieving a sample with the auger, and then continuing with the auger to the next sample depth. At the surface, each sample was placed in a quart mason jar with a Teflon-lined lid and frozen for shipment to the laboratory. Soils were analyzed for parameters listed in Table 3-3.

3.1.4.3 Surface-Water Sampling

Surface water grab samples were collected directly in the clean sample containers in order to minimize handling of the sample. There were no difficulties in gaining access to any surface-water sampling sites, located at

TABLE 3-3. ANALYTICAL SCHEDULE FOR HAND-AUGER SAMPLES, CARSWELL AFB, TEXAS

Site	Parameter						
	Oil & Grease	Lead	EP Toxicity	Pesticides	Phenols	Heavy Metals	Purgeable Organics
Flightline Drainage Ditch (13)	X		X				
Fire Training Area 1 (11)	X			X	X	X	X
Fire Training Area 2 (12)	X				X	X	X
Unnamed Stream (16)	X	X					X
Weapons Storage Area	X						X

the Unnamed Stream (Site 16), Fire Training Area 2 (Site 12), Landfill 5 (Site 5), and Landfill 4 (Site 4). At each location, observations were made regarding the condition of the stream. The analytical schedule for surface-water samples is provided in Table 3-4. The samples were preserved according to the requirements in Table 3-5.

3.1.4.4 Ground-Water Sampling

During Phase II efforts at Carswell AFB, ground-water samples were collected for analysis from the 25 ground-water monitor wells. Sampling was conducted twice at each well, the first round conducted during the first week of February 1985, and the second round of sampling conducted during the first week of March 1985. Field sampling methodologies and equipment are detailed in the following sections.

Water Level Measurements

As the first step of ground-water sampling operations at each monitor well, water level measurements were taken with an Actat Olympic well probe. The probe and associated electrical line were washed with laboratory deionized water between each well to preclude the possibility of cross-contamination. Measurements were taken to the nearest 0.01 foot with respect to the top of the protective steel well casing. Water level measurements taken prior to each sampling operation are provided in Section 4.0.

Each well was purged either immediately prior to sample collection or within one day of sample collection (for low-yield wells) to ensure that representative formation water was collected as the sample. Purging operations were conducted using either a 1.7 inch hand pump or a 1.1 liter bottom-discharge Teflon bailer. Purging operations were considered complete when three wetted well volumes had been evacuated.

All down-hole equipment used during the purging of the monitor wells was carefully washed with laboratory deionized water to prevent cross-

TABLE 3-4. ANALYTICAL SCHEDULE FOR SURFACE WATER SAMPLES, CARSWELL AFB, TEXAS

Site	Parameter								
	Heavy Metals	Purgeable Organics	COD	TOC	TOX	Oil & Grease	Lead	Pesticides	Phenols
Landfill 4 (4)		X	X	X				X	
Landfill 5 (5)		X	X	X		X		X	
Fire Training Area 2 (12)	X	X		X	X	X			X
Unnamed Stream (16) (oil/water separator, stream)		X		X	X	X	X		

TABLE 3-5. COLLECTION AND PRESERVATION OF WATER SAMPLES, CARSWELL AFB, TEXAS

Parameter	Container*	Preservation
TOC	Glass, 500 ml	H_2SO_4 to pH <2; Cool to 4°C
TOX	Glass, 500 ml	Cool to 4°C
Metals, Lead	Plastic, 500 ml	HNO_3 to pH <2; Cool to 4°C
Pesticides	Glass, 1 liter	Cool to 4°C
Phenols	Glass, 500 ml	H_2SO_4 to pH <2; Cool to 4°C
COD	Glass, 1 liter	H_2SO_4 to pH <2; Cool to 4°C
Purgeable Organics	Glass, 40 ml	Cool to 4°C
Oil and Grease	Glass, 1 quart	H_2SO_4 to pH <2; Cool to 4°C

*All containers with Teflon-lined lids.

contamination. In the case where overt evidence of chemical contamination was noted in a well (color, odor, oil, etc.) the sampling apparatus was washed with technical-grade acetone and thoroughly rinsed with deionized water.

Specific conductance and temperature were determined with the use of a conductivity and temperature meter. Temperature readings were checked using a mercury-in-glass thermometer. The pH of the discharged water was measured with the use of a pH meter. Prior to each pH measurement, the instrument was calibrated against standard solutions for pH values of 4, 7, and 10. Prior to exposure to discharge water, the selective ion probe was thoroughly washed with deionized water.

Sample Capture

After each well was purged of standing water to ensure representative ground-water characteristics, a sample was collected and split into the analytical aliquots required by the Statement of Work. Samples from wells were collected for the analyses shown in Table 3-6.

TABLE 3-6. ANALYTICAL SCHEDULE FOR GROUND-WATER SAMPLES, CARSWELL AFB, TEXAS

Site	Parameter								
	TOC	TOX	Oil & Grease	Lead	Pesticides	Phenols	Heavy Metals	Purgeable Organics	Radio-Chemical
Landfill 1 (1)	X	X	X		X	X	X	X	
Landfill 4 (4)	X		X		X	X	X	X	
Landfill 5 (5)	X	X	X		X	X	X	X	
Waste Burial Area (10)	X	X	X					X	
Fire Training Area 1 (11)	X	X	X		X	X	X	X	
Fire Training Area 2 (12)	X	X	X			X	X	X	
Entomology Building (15)	X				X				
Unnamed Stream (16) (old gas station)	X	X	X	X				X	
POL Area (17)	X	X	X						
Weapons Storage Area									X

Samples analyzed for parameters listed on Table 3-6 were placed in containers and preserved according to the requirements listed in Table 3-5. All samples were chilled to 4°C after collection. All aspects of the sampling protocol were conducted in accordance with EPA-approved methodologies. Field QA/QC measures were employed to ensure that once collected, sample integrity was maintained during shipping and handling prior to analysis. These QA/QC procedures are discussed in Appendix G.

3.1.5 Field Safety

Before the field work was initiated, a field Safety Plan was drawn up. This plan, developed from available data, anticipated likely field hazards and prescribed appropriate personnel protective equipment for the field team. Drilling and well installation in close proximity to sites 1 and 12 was expected to pose the most significant potential hazards. EPA Level C protection (impervious clothing, gloves, boots, and full-face or half-face cartridge respirators) was employed for most drilling and well installation activities. For other activities, EPA Level D protection (same as Level C, except that respirators were carried, but not worn) was deemed appropriate. The Safety Plan was followed for the complete field effort, and provided adequate protection. The complete text of the Safety Plan utilized for this project is contained in Appendix L.

3.1.6 Surveying

After all wells were installed, wellhead elevations were determined to the nearest 0.01 foot by surveying from the floor of Building 1215 (Civil Engineering). This datum provided a convenient and known reference elevation in the absence of USGS benchmarks. A local surveying firm, Sempco, Inc., accomplished this work. The report of Sempco, Inc., is contained in Appendix F.

3.2 Site Activities

The field program at Carswell AFB consisted of geophysical surveying, installation of upper zone and Paluxy monitor wells, and sampling of soil, sediment, and water. The content of the field program is presented in narrative form in the following subsections. For each of the sites that were investigated, a similar sequence of events was followed, as described in Section 3.1. Each site investigation is described separately, below.

3.2.1 Landfill 3 (Site 3)

Landfill 3 is located directly under and adjacent to the active runway at Carswell. Work at this site consisted of electromagnetic and earth resistivity surveys. No drilling, well construction, or sampling activities were performed at this site.

Two grids were established on either side of the runway. The west and east grids both measured 680 feet by 320 feet. The locations of the grids and the VES surveys are illustrated in Figure 3-7.

3.2.2 Flightline Area: Sites, 4, 5, 10, 11, 12

Several sites are located in the vicinity of the flightline at the southeast portion of Carswell AFB. Because of the proximity of these sites to each other, the investigation techniques and field activities were designed to account for the closeness of the landfills and fire training areas. Figures 3-2 and 3-3 illustrate the location of the five sites. The activities that took place in the flightline area included: performance of electromagnetic profiles, vertical electrical soundings, and magnetometer surveys; completion of sixteen upper zone and two Paluxy ground-water monitor wells, completion of two hand-augered borings, collection of surface water samples at three locations, and collection of ground-water samples at all monitor wells.

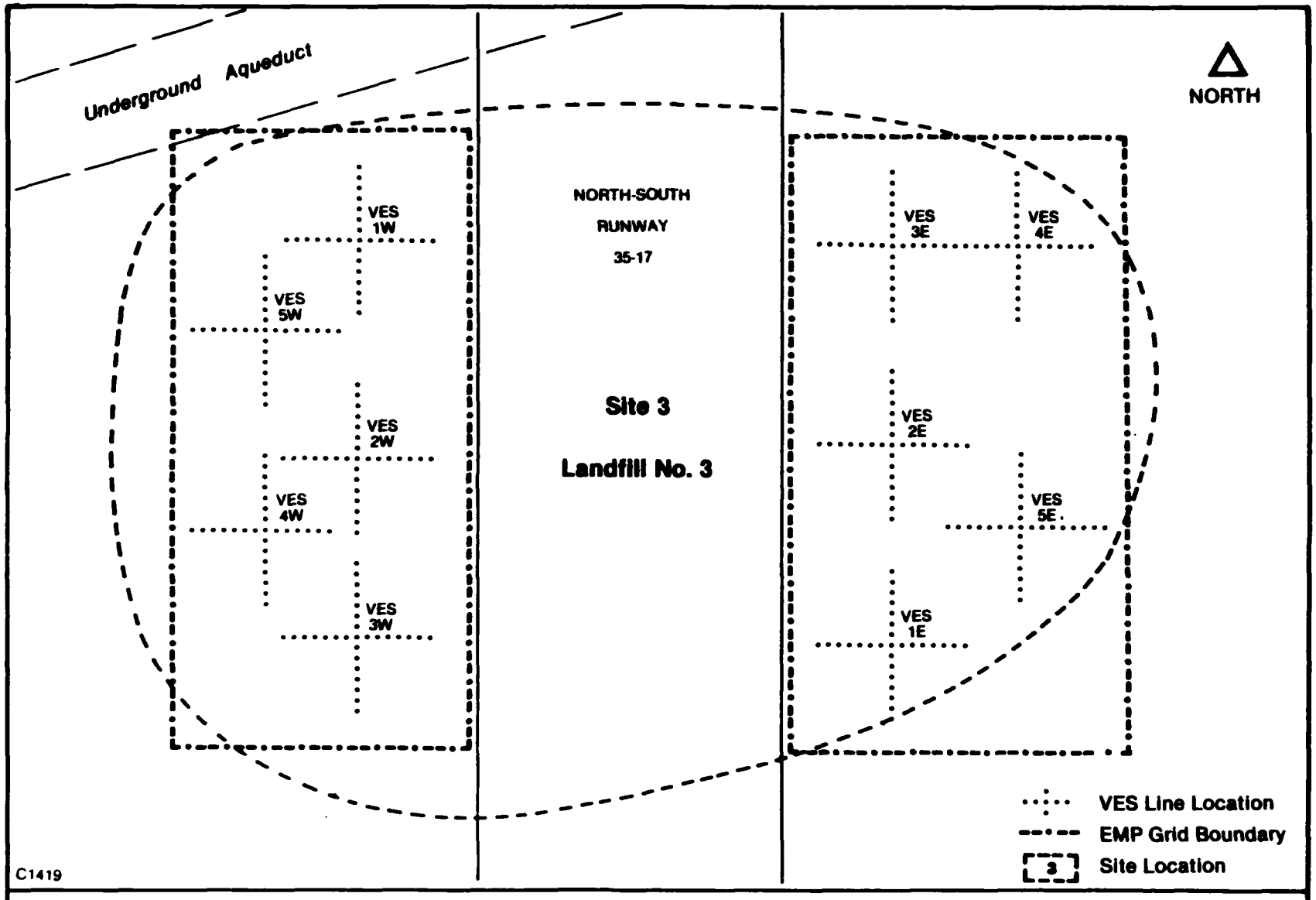

Figure 3-7. Location of Geophysical Surveys, Landfill No. 3 (Site 3).

Geophysical Surveys

A series of geophysical surveys were performed at most sites near the flightline area. The locations of the EMP and magnetometer grids are provided in Appendix K; VES stations are shown on Figures 3-2 and 3-3. The following paragraphs describe the purpose and features of the geophysical work at each site.

At Landfill 4, a grid measuring 640 feet by 480 feet was established with stations every 40 feet. Electromagnetic profile readings were taken every 20 feet within the grid, and magnetometer data were generated along the 20 foot lines with readings taken every 10 feet. Several radar buildings occupying the center of the site were avoided during the surveys. In addition, six VES lines were established as shown on Figure 3-2.

A grid for Landfill 5 was established in order to conduct EMP surveys. The grid measured 320 feet by 720 feet, with stations located every 40 feet and EMP readings made every 20 feet. Six VES lines were also established at the landfill (Figure 3-3).

The Waste Burial Area grid was established as an extension of the grid laid out for Landifll 5. The grid measured 140 feet by 160 feet, with EMP readings performed every 20 feet and magnetic readings performed every 10 feet. Two VES lines were established east of the Waste Burial Area (Figure 3-3).

The grid established for Fire Training Area 2 (Site 12) measured 560 feet by 280 feet, with the areas at the center of the training area and in the southwest corner exempted from the geophysical surveys due to interference from metal structures. As with the other sites, EMP readings were taken every 20 feet. In addition, the VES lines were established as shown on Figure 3-2.

Monitor Well Installation

A total of sixteen upper zone and two Paluxy monitor wells were installed in the flightline area (Figures 3-2 and 3-3). The following paragraphs describe the rationale for selecting locations and determining the appropriate methods of well construction.

The locations of the wells were selected both in view of the impact of individual sites on the upper zone ground water and the aggregate impact of the sites on the ground water. Because there were no ground-water quality or ground-water flow data, the primary criterion for the location of the wells was topographic setting relative to the waste disposal area. For upgradient wells ("A" series), the locations were selected upslope from the disposal sites. This criterion worked well in the selection of locations for 12A, 5A, and 11A. However, the locations of the other two upgradient wells, 10A and 4A, were modified to reflect the position of adjacent waste disposal areas (e.g., Sites 12 and 5). All downgradient wells were located downslope and as near as practicable to the limits of the waste disposal areas. All upper zone monitor wells were drilled to the base of the upper zone, or until at least 10 feet of saturated material suitable for well construction was encountered. General specifications for monitor wells installed near the flightline area are provided in Table 3-7.

The two Paluxy wells were located upgradient and downgradient of the flightline area sites. Although no data from Carswell AFB were available, ground-water flow data for the Paluxy aquifer in Tarrant County and at AF Plant 4 adjacent to Carswell AFB indicated that ground-water flow was to the east. Therefore, the two Paluxy wells were aligned in an east-west direction to monitor similar flow regimes in the aquifer.

After the completion of the monitor wells, samples of ground water were collected from each of the newly-installed wells. A second set of samples was collected approximately one month after the collection of the first set.

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TABLE 3-7. GENERAL SPECIFICATIONS FOR FLIGHTLINE AREA WELLS, CARSWELL AFB, TEXAS

Monitor Well	Measuring Point Elevation[1]	Ground Level Elevation[2]	Screened Interval[3]	Screen Elevations[2]	Total Depth[3]
4A	625.84	624.65	14-24	610.65-600.65	24
4B	620.02	618.69	13-23	605.69-595.69	24
4C	613.12	610.82	18.5-28.5	592.32-582.32	29.5
4D	615.40	613.15	18-28	595.15-585.15	30.5
4E	618.55	617.45	15-35	602.45-582.45	35
5A	623.22	619.42	18-28	601.42-591.42	32
5B	600.48	597.18	4-9	593.18-588.18	9
5C	608.73	606.63	7-22	599.63-584.63	22
10A	626.68	623.98	27.25-37.25	596.73-586.73	39
10B	624.42	620.92	23-33	597.92-587.92	36
10C	617.21	615.16	20-30	595.16-585.16	32.5
11A	608.25	604.75	4-14	600.75-590.75	14.5
11B	608.11	603.56	3.5-13.5	600.06-590.06	15
12A	635.66	631.76	13-23	618.76-608.76	25
12B	627.59	625.56	27.5-37.5	598.06-588.06	40
12C	626.07	625.44	27.5-37.5	597.94-587.94	38
P1	626.19	625.59	69-109	556.59-516.59	109.4
P2	618.42	615.79	69.5-109.5	546.29-506.29	109.6

[1] Top of PVC for monitor wells, except P1 and P2 (top of access hole).
[2] Feet, msl to nearest 0.01 foot. (Reference Datum = floor of Bldg. 1215).
[3] Feet below ground level.

Upper Zone Monitor Well Sampling

After the completion and initial development of the monitor wells, each one was purged and sampled. Field sampling was conducted by Radian personnel during the periods 4-8 February 1985 and 4-8 March 1985. Details of the field procedures are presented in Section 3.1.4.4. The ground-water samples were analyzed for the parameters as shown in Table 3-5. Results of the ground-water analyses are provided in Section 4.0.

Other Sampling

In addition to monitor well sampling, surface-water samples and soil samples were collected for analysis. Locations of surface water and hand-auger sampling points are shown on Figures 3-2 and 3-3. Procedures used in the sampling activities are as described in Section 3.1.4.2 and 3.2.4.3.

Aquifer Tests

Two aquifer tests were performed on the Paluxy wells as part of the sampling activities conducted in late March, 1985. The tests were conducted by observing the response of water levels in wells P-1 and P-2 both during and after pumping. Each pump test was performed as follows: first, the static water level in the well was measured; second, the submersible pump was started and the response of the water level to pumping was measured at frequent intervals; and third, the discharge rate was measured at periodic intervals. Plots of drawdown versus time were made during the test in order to judge the optimal duration for each test. After pumping was stopped, the recovery of the water level was measured at similar intervals as used during the pumping test. The recovery data were plotted against time and compared to the data obtained during the pumping phase of the test.

Results of the recovery test data are provided in Section 4.0; these results were used rather than the pumping test data owing to the possible influence of well loss and pump turbulence during the pumping phase of the tests.

3.2.3 East Area: Sites 1, 13, 15, 16, 17

Several sites are located near the main gate at Carswell AFB and are collectively described as the East Area sites. Work at these locations included: performance of electromagnetic profiles, vertical electrical soundings, and magnetometer surveys; completion of seven upper zone monitor wells and completion of ten borings using a hollow-stem auger drilling rig, completion of eight hand-augered borings; collection of surface water and sediment samples at several loctions, and collection of ground-water samples at all monitor wells and coreholes.

The following paragraphs provide additional details on the performance of field activities in the East Base area.

Geophysical Surveys

A series of geophysical surveys were performed at Sites 1 and 16. The following paragraphs describe the purpose and features of the geophysical work at each site.

Landfill 1 lies under the DPDO yard, rendering the use of some geophysical techniques impractical due to interferences from metal and buried objects. Because of these considerations, the magnetic survey was deleted from the scope of work. The grids of the EMP surveys were established on the east and west flanks of the yard. The grid dimensions were established at 60 feet by 680 feet at the Trinity River and 80 feet by 280 feet at the western boundary of the yard (Figure 3-4). Stations were located every 40 feet, with EMP readings taken at 20-foot intervals. In addition, four VES sites were surveyed outside the DRMO yard in order to determine the thickness and character of the alluvial material.

The purpose of the geophysical survey at Site 16 was to locate buried tanks reportedly existing at the former location of the base service station. A magnetometer survey was performed in the area of the service station. The dimensions of the grid were 200 feet by 160 feet.

Monitor Well Installation and Borehole Drilling

A total of seven upper zone monitor wells were installed at Sites 1 and 15 (Figures 3-4 and 3-5) and a total of eleven borings were drilled at Sites 16 and 17. The following paragraphs describe the rationale for selecting locations and determining the appropriate methods of well construction.

The locations of the wells and borings were considered in view of the impact of individual sites on the upper zone ground water. There were no ground water quality or flow data available to aid in the selection of well locations. The primary criterion for the location of the wells was topographic setting relative to the waste disposal area to be monitored. For upgradient wells ("A" series), the locations were selected upslope from the disposal sites. Downgradient wells were located downslope and as near as practicable to the limits of the waste disposal areas. All upper zone monitor wells were drilled to the base of the upper zone, or until at least 10 feet of saturated zone was encountered. General specifications for monitor wells and borings completed near the east base area are provided in Table 3-8.

After the completion of the monitor wells, samples of ground water were collected from each of the newly-installed wells. A second set of samples was collected approximately one month after the collection of the first set. Soil samples were collected from wells and borings as drilling progressed. Water samples were collected after drilling was complete and before the holes were filled with grout.

Sampling Activities

After the completion and initial development of the monitor wells, each one was purged and sampled. Field sampling was conducted by Radian personnel during the periods 4-8 February 1985 and 4-8 March 1985. Details of the field procedures are presented in Section 3.1.4.4. The ground-water samples were analyzed for the parameters as shown in Table 3-5. Results of the ground-water analyses are provided in Section 4.0.

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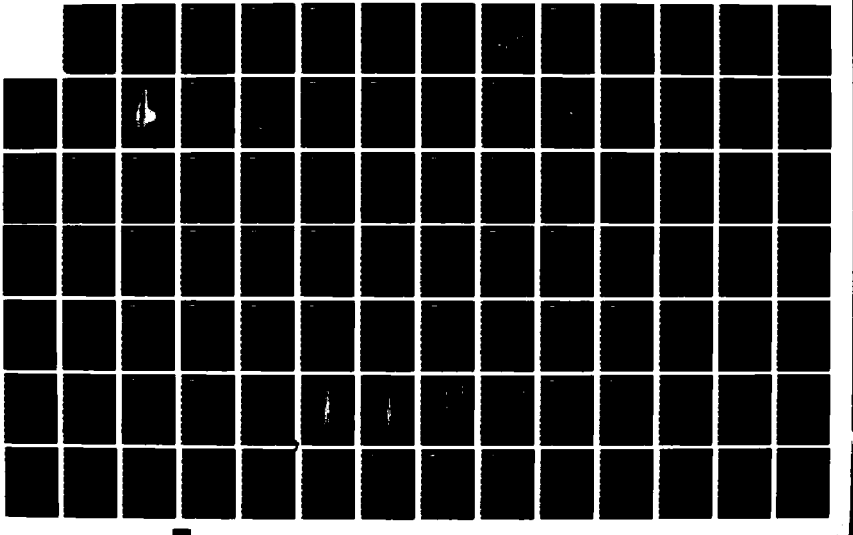

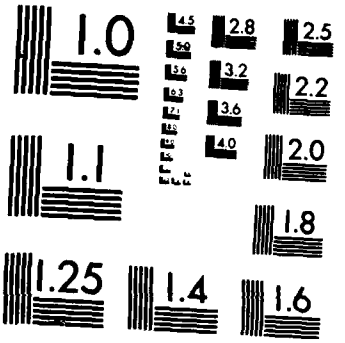

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TABLE 3-8. GENERAL SPECIFICATIONS FOR WELLS AND BORINGS IN THE EAST BASE AREA, CARSWELL AFB, TEXAS

Monitor Well or Boring	Measuring Pt. Elevation[1]	Ground Elevation[2]	Screened Interval	Screen Elevations	Total Depth[3]
1A	570.42	566.62	2.75-7.75	563.87-558.87	7.75
1B	560.24	560.69	9-19	551.69-541.69	19.07
1C	560.03	560.46	23-33	537.46-527.46	33.06
1D	564.06	560.46	13-23	547.46-537.46	23.26
15A	570.24	570.62	2.5-12.5	568.12-558.12	12.74
15B	568.09	564.14	2-7	562.14-557.14	7.43
15C	567.87	564.17	5.5-10.5	558.67-553.67	10.66
16A	568.44	568.44	NA[4]	NA	13.5
16B	569.67	569.67	NA	NA	13.0
16C	565.35	565.35	NA	NA	8.0
17A	580.13	580.13	NA	NA	20.0
17B	578.48	578.48	NA	NA	20.0
17C	574.27	574.27	NA	NA	20.0
17D	573.05	573.05	NA	NA	18.0
17E	574.99	574.99	NA	NA	20.0
17F	572.87	572.87	NA	NA	17.5
17G	573.20	573.20	NA	NA	17.0
17H	573.66	573.66	NA	NA	18.5

[1]Top of PVC for monitor wells.

[2]Feet, msl to nearest 0.01 foot (Reference Datum = floor of Bldg. 1215).

[3]Feet below ground level.

[4]NA = Not applicable, screens not installed in borings.

4.0 DISCUSSION OF RESULTS AND SIGNIFICANCE OF FINDINGS

In this section, the geophysical data, hydrogeologic observations and chemical analyses are discussed on a site-by-site basis. Conclusions regarding subsurface conditions are made on the basis of available hydrogeologic and geophysical data. Analytical chemistry data are discussed within the context of available regulatory standards and criteria. After an introduction section dealing with available standards and criteria, the discussion of results and significance of findings for each site are discussed in separate sections.

4.1 Regulatory and Human Health Criteria and Standards

In order to determine possible water quality impacts on the groundwater, the organic and inorganic compounds detected in the ground-water samples were compared to various criteria. These criteria were drawn from federal drinking water regulations, standards and guidelines. Table 4-1 shows parameters detected at Carswell AFB, along with the corresponding primary or secondary drinking water standard. These standards provide a stringent comparison for human health considerations.

Table 4-2 lists EPA toxicity values and human health criteria which are available for most of the organic chemicals detected. Although these criteria do not have the force of standards, they do provide a valid means of assessing properties of chemicals of concern. Many of the compounds are proven or suspected animal carcinogens where zero consumption is recommended for the protection of human health. Many are also regulated as hazardous waste under RCRA (40 CFR Parts 262 and 263). For each site, parameters detected are evaluated in comparison with these standards and criteria. Table 4-3 lists the normal ranges of heavy metal concentrations in soils. Natural occurrences of metals can be far above and below the normal range, depending on local geologic conditions. No guidelines exist regulating the metals content of soils;

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TABLE 4-1. REGULATORY STANDARDS OR CRITERIA FOR DRINKING WATER ANALYSES

Parameter[1]	Federal Standard (mg/L)
Arsenic	0.05
Barium	1.0
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Selenium	0.010
Silver	0.050
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
2,4-D	0.1
2,4,5-TP (silvex)	0.01
Radium 226 & 228	5 pci/L
Gross Alpha	15 pci/L
Gross Beta	50 pci/L

[1] Regulatory references: Federal Register 24 October 1980 and 7 September 1979.

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TABLE 4-2. GUIDELINES FOR ORGANIC COMPOUNDS DETECTED IN GROUND WATER

Compound	EPA Toxicity[1,2] (ppb unless noted)
Vinyl Chloride	0(20)
Chloroethane	N.C.[3]
Methylene Chloride	0(1.9)
Trichlorofluoromethane	0(1.9)
1,1-Dichloroethene	0(0.33)
1,1-Dichloroethane	0(9.4)
1,1,1-Trichloroethane	18.4 ppm
1,4-Dichlorobenzene	400
1,1,2,2-Tetrachloroethane	0(1.7)
1,2-Dichloropropane	N.C.
Trichloroethylene	0(27)
Tetrachloroethylene	0(8)
Chlorobenzene	488
trans 1,2-Dichloroethane	N.C.
1,2-Dichlorobenzene	400
1,3-Dichlorobenzene	400
Benzene	0(6.6)
Ethyl Benzene	1.4 ppm
Toluene	14.3 ppm
Phenols	3.5 ppm

[1]EPA estimate of safe levels of toxicants in drinking water for human health effects (Federal Register, 28 November 1980).

[2]EPA has recommended human health effects criteria of zero (0) for carcinogens, but notes that this level may currently be infeasible. The Agency provides criteria for achieving various levels of protection on an interim basis. The levels which may result in a 10^{-5} incremental increase of cancer risk over a lifetime are presented in parentheses in ppb unless noted. These levels would permit one case of cancer per 100,000 people exposed.

[3]N.C. - denoted no criteria set for human health due to insufficient data.

TABLE 4-3. NORMAL RANGES OF HEAVY METAL CONCENTRATIONS FOUND IN SOILS

Metal	Normal Range (ppm)
Ba	100-500
Cr	10-50
Pb	2-20
As	5-10
Se	0.2-0.6
Ag	0.04-0.1
Cd	0.06
Hg	unknown

Source: Rose, A.W., H.E Hawkes, and J.S. Webb, 1979, Geochemistry in Mineral Exploration: Academic Press, New York, 675p.

therefore, measured concentrations are compared to the normal ranges given in Table 4-3 and are also compared to apparent background levels at each site.

The use of human health criteria and standards for comparison of ground-water contamination at Carswell AFB provides stringent evaluations of observed concentrations. Since the upper zone groundwater is not used as a water source, contaminants in-situ do not have human health consequences. As these contaminants exit from the upper zone ground-water system, they encounter potential receptors. Carswell AFB is underlain by the regionally important Paluxy aquifer at depths less than 100 feet. If contaminants are recharged to that regional system, they would have direct human health implications. Where waters come to the land surface, either as seeps or as groundwater outflow to streams, there exists the potential for human contact and exposure. Within the context of the IRP program, the installation boundary is considered to be a de-facto receptor with human health implications. If alternative (less stringent) limits were established specifically for Carswell AFB, a formal risk assessment would be required. Since the formal assessment of environmental and human health risks associated with the occurrence of contaminants is beyond the scope of this program, the use of human health standards and criteria is both reasonable and prudent.

4.2 Results of Phase II (Stage 1) Investigation

This section presents the results of geologic, hydrologic, and chemical data obtained during the Phase II Stage 1 investigation. The discussions are organized by site or activity, with appropriate references to base-wide trends or features common to more than one site. Figure 4-1 shows the areas of investigation for the the Phase II Stage 1 investigation. Results from the work performed in each area are presented in terms of the topography, geology and hydrology, and water quality observed during the investigation.

During the soil and water sampling activities described below, duplicate samples were collected and analyzed at an approximate 10% frequency.

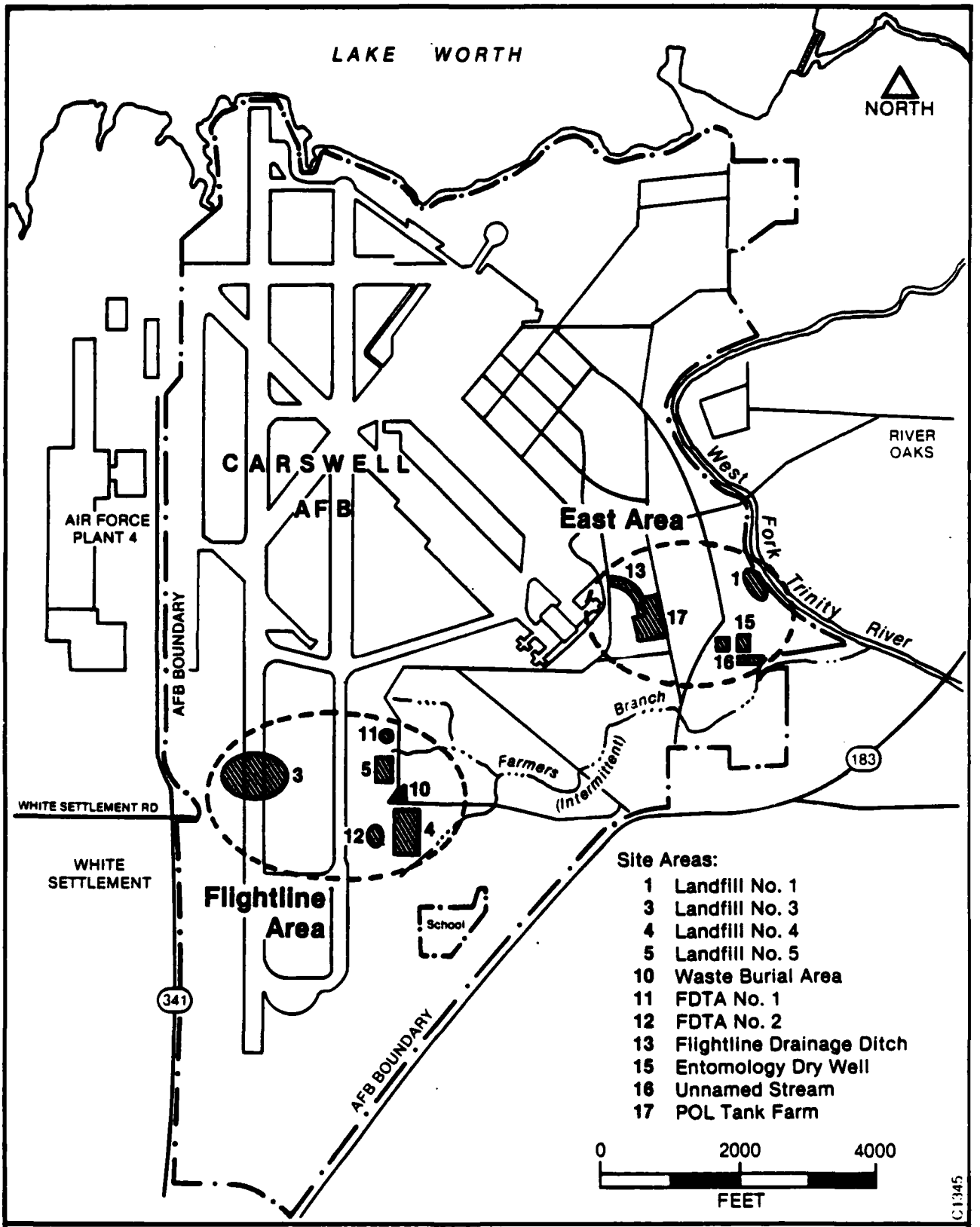

Figure 4-1. Location of Phase II Stage 1 Sites, Carswell AFB, Texas.

From time to time, these duplicate analyses did not agree. This is especially true of oil and grease analyses in soils. Careful evaluation of the data reveal that these variations may properly be ascribed to sampling variability, not analytical error. Results are presented without comment in the balance of the report.

Sites investigated during the Phase II Stage 1 investigation are located in two areas as illustrated in Figure 4-1. For simplicity of discussion, the two major areas investigated are referred to as the Flightline area and the East area. The Flightline area consists of Landfills 3,4, and 5, Waste Burial Area, and Fire Training Areas 1 and 2. The East area consists of the Flightline Drainage Ditch, POL Storage Tanks, the Unnamed Stream, the old Entomology Building, and Landfill 1 (DRMO). Because of the geologic and topographic similarities of sites within each of the areas, a broad overview of the features and data common to sites within an area is given as in introduction to the details of the investigation at each particular site.

4.2.1 Flightline Area Investigation

Work performed in the vicinity of the flightline (Landfills 3,4, and 5, Waste Burial Area, and Fire Training Areas 1 and 2) consisted of the installation of sixteen upper zone monitor wells, two Paluxy wells, a series of geophysical investigations, and sampling and analysis of soil and water. Following an overview of the common feature of the various sites, the hydrogeologic and chemical data for each of the sites are discussed.

Topography

The area in the vicinity of the flightline ranges from an essentially level surface near the main (N-S) runway to gently rolling land near tributaries of Farmers Branch at the golf course. All of the land is underlain by terrace deposits of the Trinity River. The terrace deposits have been dissected by tributaries of Farmers Branch. Elevations in the area range from

625 feet msl at Landfill 3 to 580 feet msl at the northern end of Landfill 5 and at Fire Training Area 1.

Drainage in the flightline area is generally to the north and east toward Farmers Branch and the Trinity River. During the investigation, it was noted that water was present in tributaries to Farmers Branch at the southwest side of Landfill 4 and at the northern end of Landfill 5 and east of Coody Drive. Southwest of Landfill 4, the stream flows over limestone and shale outcrop, but becomes an influent stream as water percolates into terrace deposits south and east of the landfill. The other tributary west of Landfill 5 and Site 12 becomes effluent at Coody Drive where terrace deposits are relatively thin.

Geophysical Surveys

Geophysical surveys, consisting of a combination of electromagnetic profiling (EMP), earth resistivity vertical electrical soundings (VES), and magnetometer surveys, were conducted at all sites in the flightline area. The purpose of the surveys was to provide indirect information on the character of subsurface materials, including significant variations in thickness of geologic units, occurrence of buried objects, the position of the water table, and occurrence of soil and ground-water contamination.

It is important to consider the geophysical data obtained at the flightline area as indirect measurements of the thickness and character of the subsurface. The geoelectric properties of the subsurface may or may not correspond to actual stratigraphic and lithologic features. Therefore, all geophysical data are viewed within the context of the available direct measurements from drilling operations and soil and ground-water sampling and analysis. In addition, the conclusions developed from some of the geophysical data, particularly the VES data, do not have unique interpretations. A summary of general observations and results at the flightline area from each of the

geophysical techniques is provided below, with additional details provided in the individual site sections later in the chapter.

Electromagnetic Profiling Results of EMP indicate that the flightline area is underlain by materials with background conductivities in the range of 30 to 60 millimhos/meter. Apparent conductivity usually increases with depth, attributable to several phenomena: the occurrence of ground water in the upper zone at depths ranging from 10 to 30 feet below the surface, increasing grain-size with depth, and the presence of limestone and shale underlying the upper zone deposits.

Vertical Electrical Sounding Results of the VES surveys suggest that a stratified subsurface, consisting of several layers of variable thickness, occurs at the flightline area. In several areas, the thickness and depth of resistivity horizons are in close agreement with boring results; in other areas the interpretations of the VES data do not correspond with observed lithologic or stratigraphic conditions. However, in virtually all areas, the VES data demonstrate that there are no significant lateral resistivity changes across the flightline area. In addition, the composite data indicate that the area has a relatively high surface resistivity, decreasing with increasing electrode separation to 10 meters (AB/2). These data, corroborated by the EMP data, suggest a two-layer geologic model with a high resistivity layer near the surface, grading to a lower resistivity materials with increasing depth. Observations from the boring operations revealed that there is a general increase in grain size (gravelly clays and silts at the land surface to coarse gravel and sand at depth) with depth. With an electrode spacing greater than 10 meters (AB/2), the subsurface resistivity increases. It is probable that the rising VES curve (for AB/2 greater than 10 meters) represents the occurrence of indurated limestone and shale of the Goodland Formation.

Magnetometer The results obtained from the magnetometer survey conducted at Site 10 do not offer information related to the natural geologic

conditions underlying the area. The purpose of the magnetometer survey was to locate buried metallic objects; the results of the survey are discussed site-by-site in later sections.

Geologic Features

Subsurface conditions in the flightline area have been revealed by indirect geophysical measurements and by direct sampling and observation through drilling operations. Methods of investigation are discussed in Chapter 3.

Upper zone deposits consist of unconsolidated alluvium and fill materials that underlie the entire flightline area, with the exception of outcrops of limestone and shale southwest of Landfill 4 and south of Fire Training Area 2. The alluvium consists of flood-plain and fluviatile terrace deposits of gravel, sand, silt, and clay that occur as a veneer on the eroded surface of the Goodland Limestone.

The base of the upper zone deposits was identified during the Phase II drilling activities. Results of drilling indicate that the upper zone deposits consist of 13 feet to greater than 39 feet of interbedded clay, silt, sand, and gravel. In general, silt and clay with variable amounts of sand and gravel occur at the land surface down to depths of 5 to 10 feet. Underlying the silt and clay is a sand and gravel unit that normally increases in grain size with increasing depth. These strata appear to be relatively continuous across the area of investigation, although coarse gravel deposits occur in limited areas generally east of Coody Drive. The sand deposits are fine to coarse grained, tan to rust in color, and composed dominantly of quartz grains. Gravel is mostly limestone and shell fragments ranging up in size from fine gravel to cobbles.

Limestone and shale of the Cretaceous-age Goodland and Walnut Formations underlie the upper zone deposits. These formations were observed both

during drilling of the Paluxy wells and selected upper zone wells. Both formations consist of interbedded fossilferous hard limestone and calcareous shale. These strata are generally dry, although small amounts of water are present in the shale and clay units. Directly below the Goodland/Walnut Formations is the Paluxy Formation. The Paluxy is composed of gray, friable quartz sandstone with interbedded shale and occasional lignite strata.

The base of the upper zone deposits has been identified during the Phase II drilling activities. Geologic cross-sections, constructed for the Flightline area, cover the areas shown on Figure 4-2. Figures 4-3 and 4-4 illustrates the configuration of the contact between the upper zone and the underlying limestone and shale (herein referred to as "bedrock"). The bedrock surface is generally level across most of the flightline area (its position is not directly known at Landfill 3), with a pronounced rise in the southwest portion of the area of investigation corresponding to the outcrop occurrence of limestone and shale. The irregular topography of the bedrock is characteristic of an erosional surface modified by fluvial processes, documented by a sequence of interbedded fluviatile gravel, sand, silt, and clay.

Occurrence of Ground Water

Ground water occurs in the upper zone and Paluxy aquifer underlying the flightline area. Table 4-4 provides the results of water level measurements made at monitor wells in the Flightline area. A potentiometric surface map (Figure 4-5) of the flightline area reveals that the elevation of the ground water table in the upper zone generally reflects the shape of the contact between the bedrock and the upper zone. This is particularly evident in the area of Fire Training Area 2, where both the contact and the water table have steep gradients. The position of the water table also reflects to a lesser degree the overlying topography; downgradient is generally to the east, as is the slope of the land surface. A steep hydraulic gradient occurs only in the extreme southwest part of the area; most of the flightline area has a very low hydraulic gradient as seen by the widely-spaced contours at Sites 5

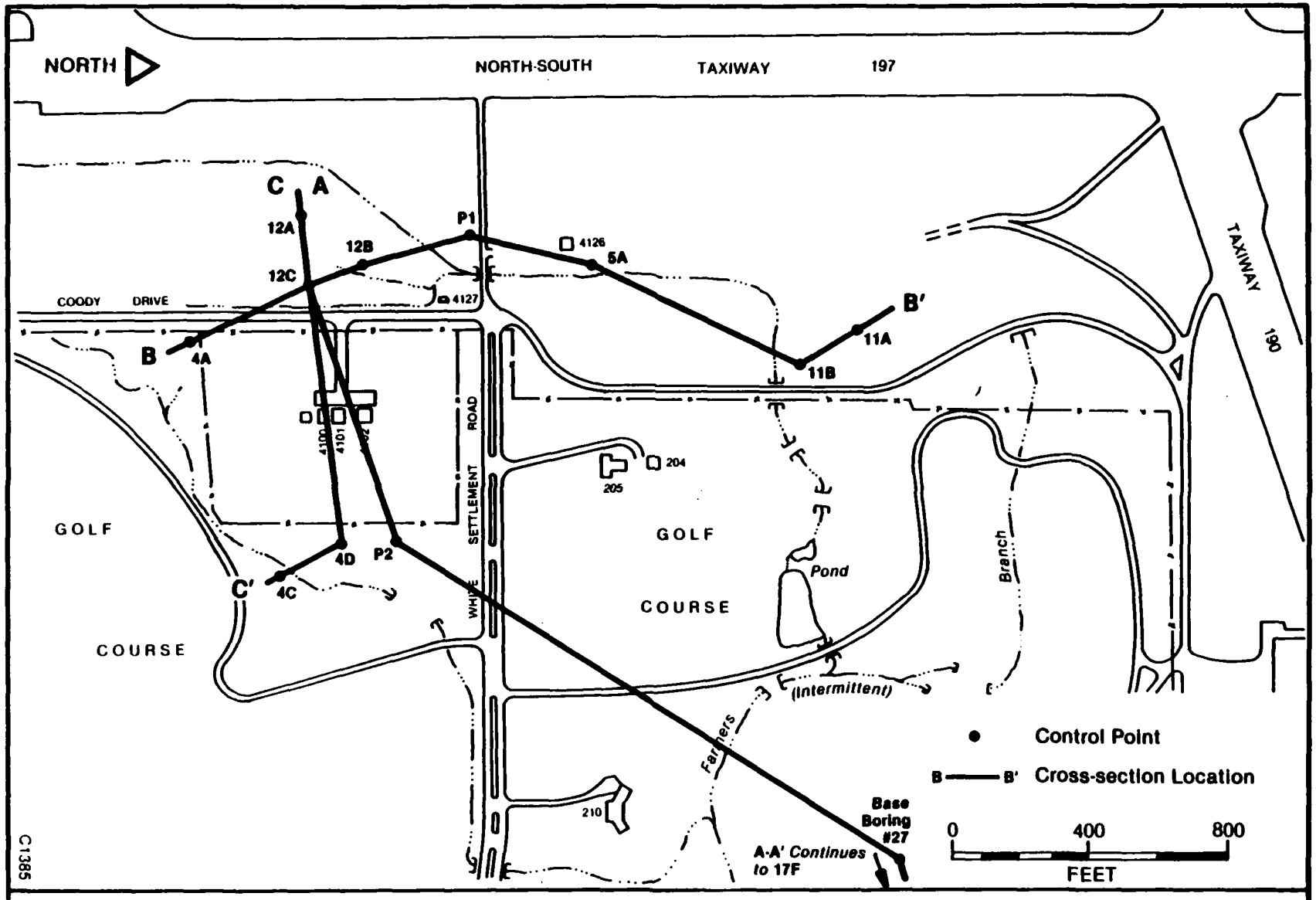

Figure 4-2. Detail of Flightline Area and Cross-Section Locations, Carswell AFB, Texas.

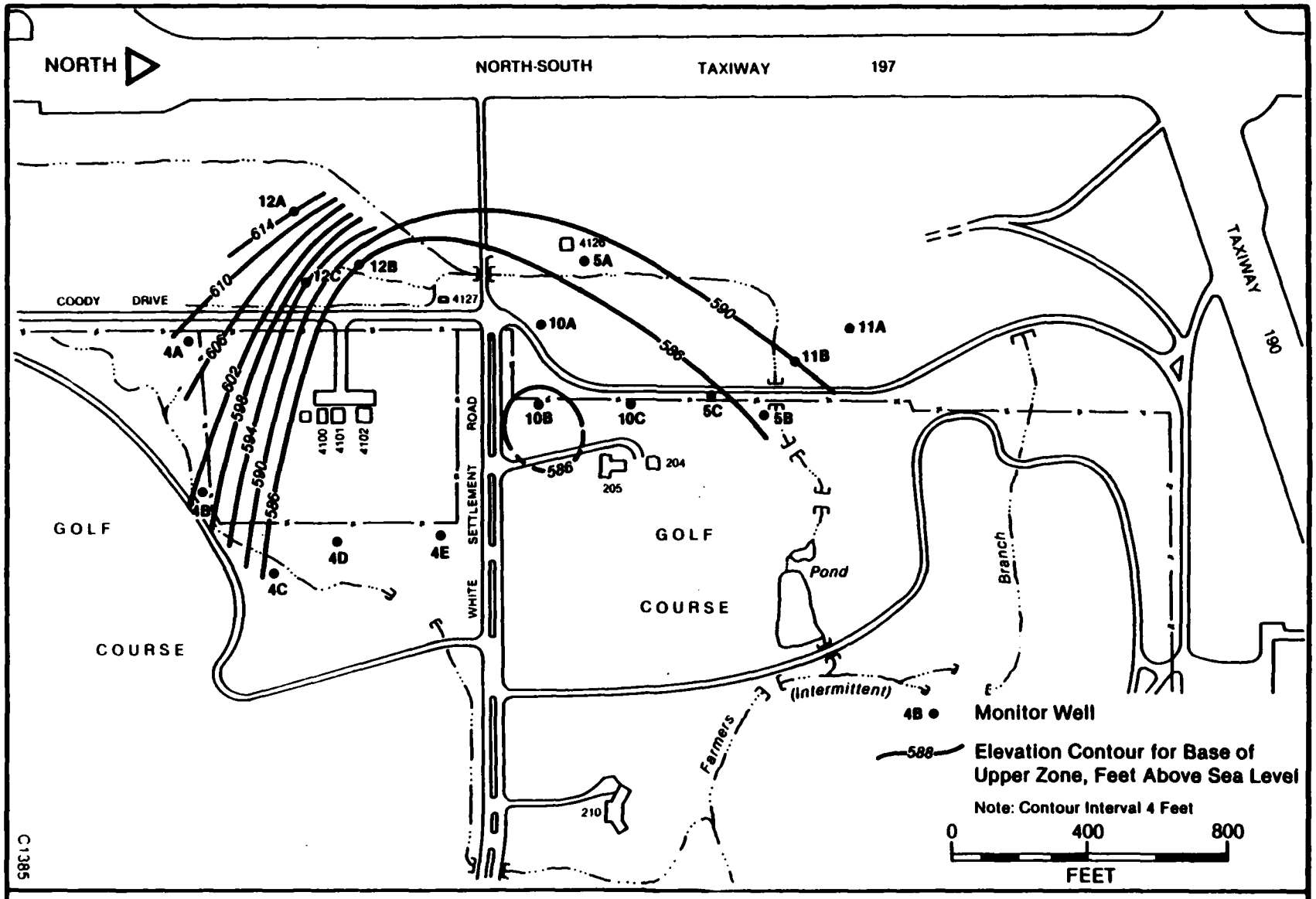

Figure 4-3. Contour Map of the Base of the Upper Zone, Carswell AFB, Texas.

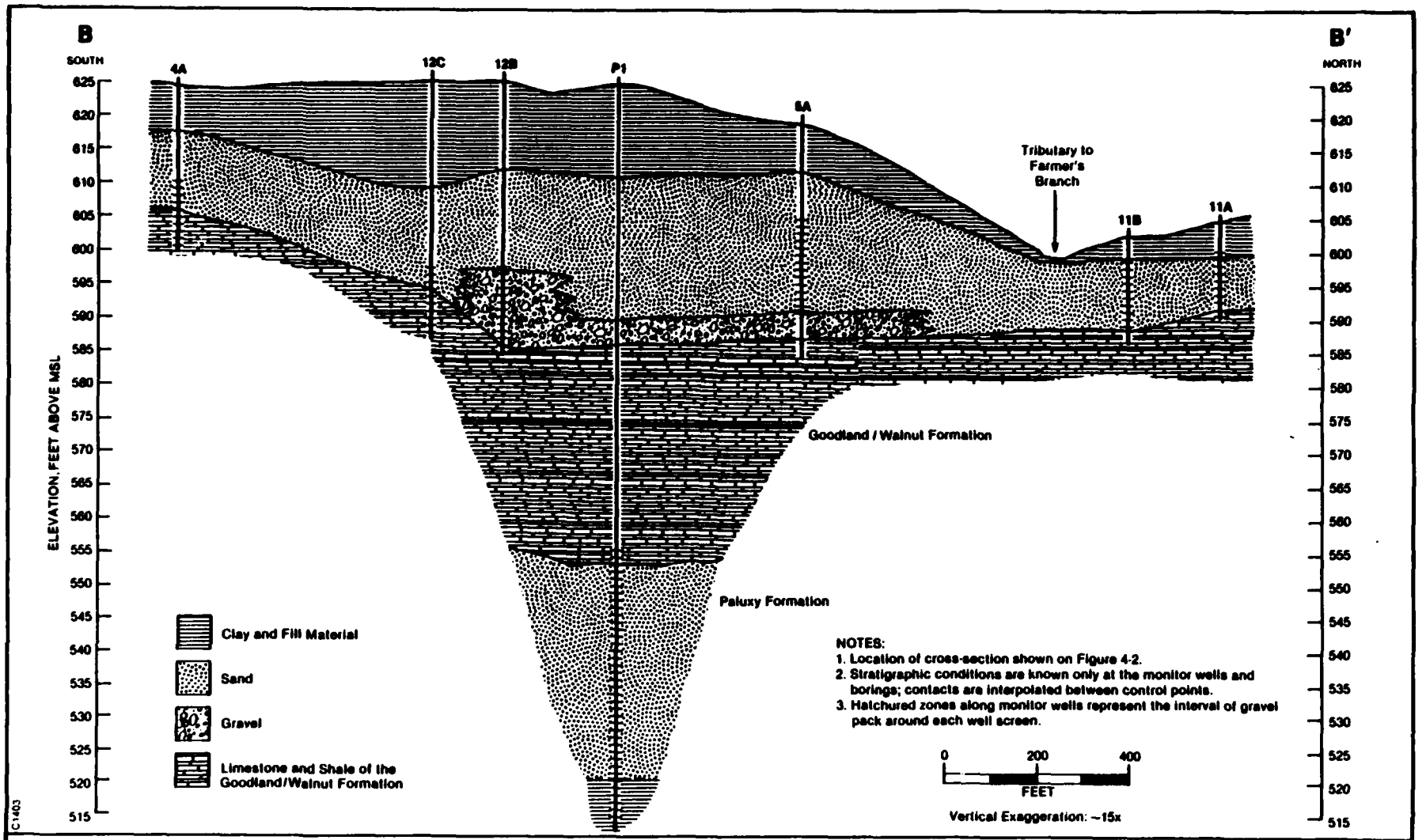

Figure 4-4. Geologic Cross-Section B-B', Carswell AFB, Texas.

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TABLE 4-4. RESULTS OF WATER LEVEL MEASUREMENTS[1], FLIGHTLINE AREA, CARSWELL AFB, TEXAS

Monitor Well[2]	Date		
	Feb. 4-8	March 4-8	March 26
4A	614.94	615.15	
4B	601.34	602.73	
4C	593.93	594.10	
4D	594.45	594.53	
4E	594.23	594.09	
5A	597.16	597.22	
5B	595.48	595.44	
5C	596.39	596.44	
10A	596.75	596.86	
10B	595.62	595.71	
10C	595.74	596.00	
11A	595.52	595.66	
11B	597.32	597.26	
12A	617.86	618.35	
12B	595.82	595.97	
12C	595.60	595.72	
P1		545.69	545.65
P2		542.90	542.73

[1] Elevations in feet (msl).
[2] Wells P1 and P2 were not constructed until late February, 1985.

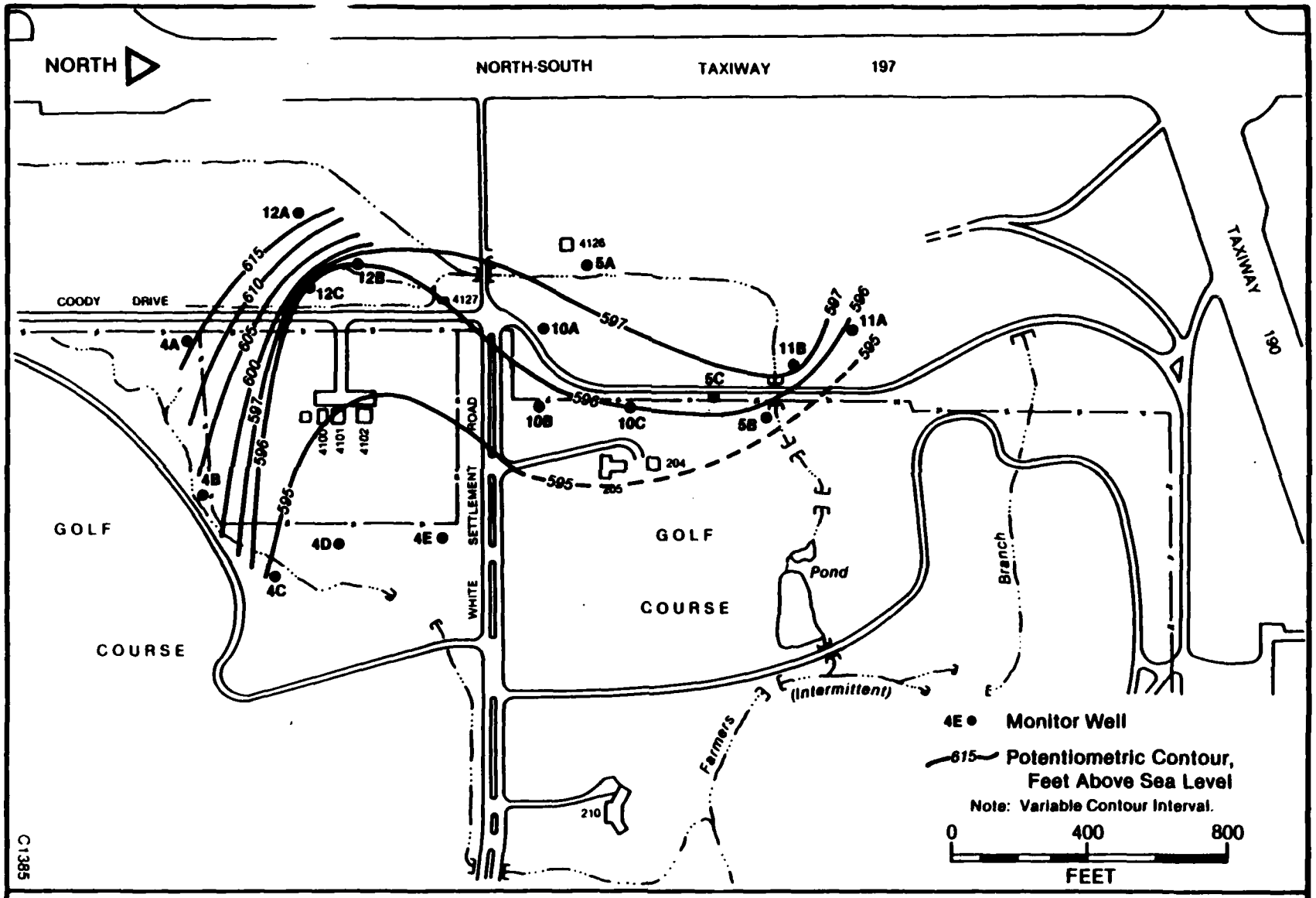

Figure 4-5. Potentiometric Surface Map of the Upper Zone, Flightline Area, Carswell AFB, Texas.

and 10. Ground-water flow is dominantly to the east, as seen from Figure 4-5 which indicates decreasing hydraulic head in an eastward direction.

Water Quality

Results of ground-water, surface-water, and soil sampling performed in the flightline area are provided and discussed on a site-by-site basis.

4.2.1.1 Landfill 3 (Site 3)

Work performed at Landfill 3 (Site 3) consisted of geophysical surveys (EMP, VES). Monitor well installation work and soil boring activities were not conducted at this site.

Landfill 3 is believed to be located directly underneath and on both sides of the main runway. The site is approximately 600 feet south of the underground aqueduct that carries the flow of Farmers Branch. Because no surveys could be conducted on the runway itself due to steel reinforcement of the concrete, a grid was set up on both sides of the runway (Figure 3-7).

Ground conductivity was read directly using the Geonics EM31 and EM34-3. By using both the EM31 and EM34-3, the apparent conductivities were measured at three different depths of investigation. The depth of investigation was approximately 10 feet with the EM31 (horizontal dipoles), 20 feet with the EM-31 (vertical dipoles), and 50 feet with the EM34-3 with 20 meters of separation (see Section 3.1.1). With measurements at two different depths of investigation, an estimate can be made of the thickness of the area of interest. The values measured at each station are shown in conductivity maps in Appendix K.

The EM31 (horizontal dipoles) shows background values of conductivity between 40 to 60 millimhos/m over most of the area on both the east and west sides of the runway. Background conductivity readings for the EM31

(vertical dipoles) generally ranged from 50 to 80 millimhos/m and background conductivity values for the EM34-3 generally ranged from 60 to 90 millimhos/m over the area of investigation. Thus, a general increase in conductivity is observed with increasing depth throughout the Landfill 3 area. Lateral variations in conductivity are most likely due to variable soil conditions. All conductivity maps indicate the presence of high-conductivity anomalies, primarily associated with cultural features such as the runway.

Data from VES sites show low resistivities for the entire depth of exploration. Sites on the south side on the east grid appear to have detected bedrock at 12 to 14 meters, but there are no subsurface coring data to confirm the model.

4.2.1.1 Landfill 4 (Site 4)

Activities conducted at Landfill 4 consisted of geophysical (EMP, VES) surveys, installation of upper zone monitor wells, installation of a Paluxy monitor well, and collection of surface-water samples. Figure 4-6 illustrates the locations and limits of the geophysical surveys, monitor wells, and surface water sampling points. The results of the hydrogeologic and geophysical investigations, and chemical data are discussed in the following paragraphs.

Topography

Landfill 4 is located in the southern part of Carswell AFB at the intersection of White Settlement Road and Coody Drive. The land surface ranges in elevation from 625 feet to 615 feet msl. The site is now occupied by the radar installation (Bldgs. 4100, 4101, and 4102). The disposal area is visible as a hummocky surface corresponding to the locations of trenches and filled areas. Surface drainage is generally to the east to an unnamed tributary of Farmers Branch.

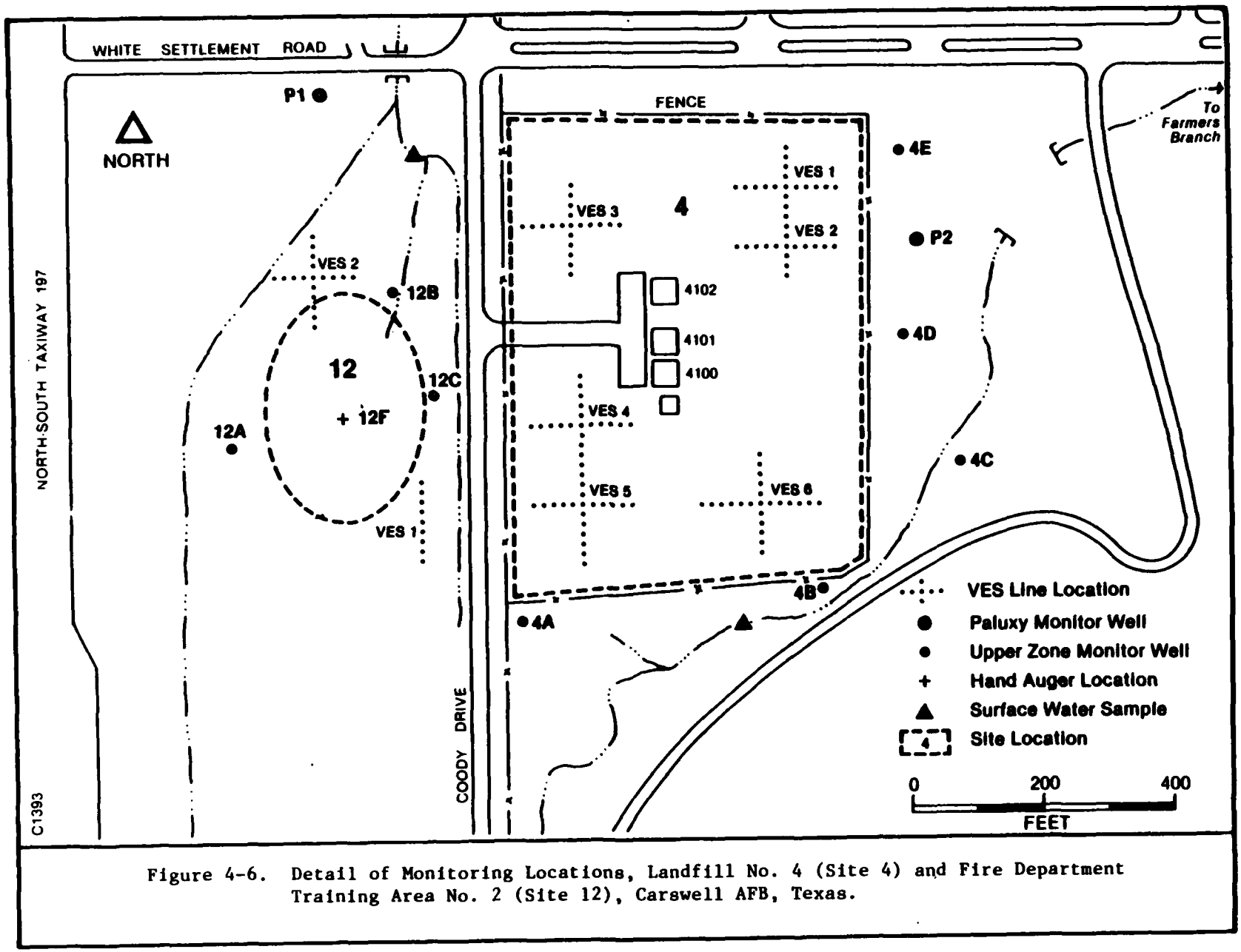

Figure 4-6. Detail of Monitoring Locations, Landfill No. 4 (Site 4) and Fire Department Training Area No. 2 (Site 12), Carswell AFB, Texas.

Geologic Features

Geologic data developed for Landfill 4 resulted from three activities: geophysical surveys (EMP and VES), geologic sampling during drilling operations, and observations of water levels during and after monitor well installation.

The geologic picture at Landfill 4 is consistent with the overall setting of the Flightline sites. Upper zone materials consist of clayey silt with variable amounts of fine sand and gravel in turn underlain by sand and gravel deposits. Figure 4-7 illustrates the geologic section from west of Landfill 4 eastward to the tributary to Farmers Branch. The thickness of the upper zone ranges from 17 feet at monitor wells 4A and 4B to 34 feet at monitor well 4E. Generally, the surficial clay and silt deposits are 5 to 10 feet thick and the sand and gravel deposits are 10 to 30 feet thick. It was observed that in most borings in the vicinity of the flightline the grain size of the sand and gravel increases with depth. At the base of the upper zone, borings east of the landfill (4C, 4D, 4E) encountered coarse gravel and cobbles (Figure 4-7).

Shale and limestone of the Goodland Formation underlie the upper zone materials at all locations. The top of the Goodland occurs at a maximum depth of 34 feet in the northeast corner of the site (at 4E) and at its shallowest depth of 17 feet in the south (at 4A and 4B). Limestone of the Goodland Formation crops out just south of the landfill in a stream that flows to Farmers Branch. The bedrock/upper zone contact slopes to the northeast under the landfill, particularly in the southwest quadrant of the landfill. Figure 4-3 illustrates the elevation of the contact between the upper zone materials and the underlying limestone and shale.

Drilling at P2 just east of the landfill revealed that the Goodland and Walnut Formations are 40 feet thick. The Paluxy Formation underlies the

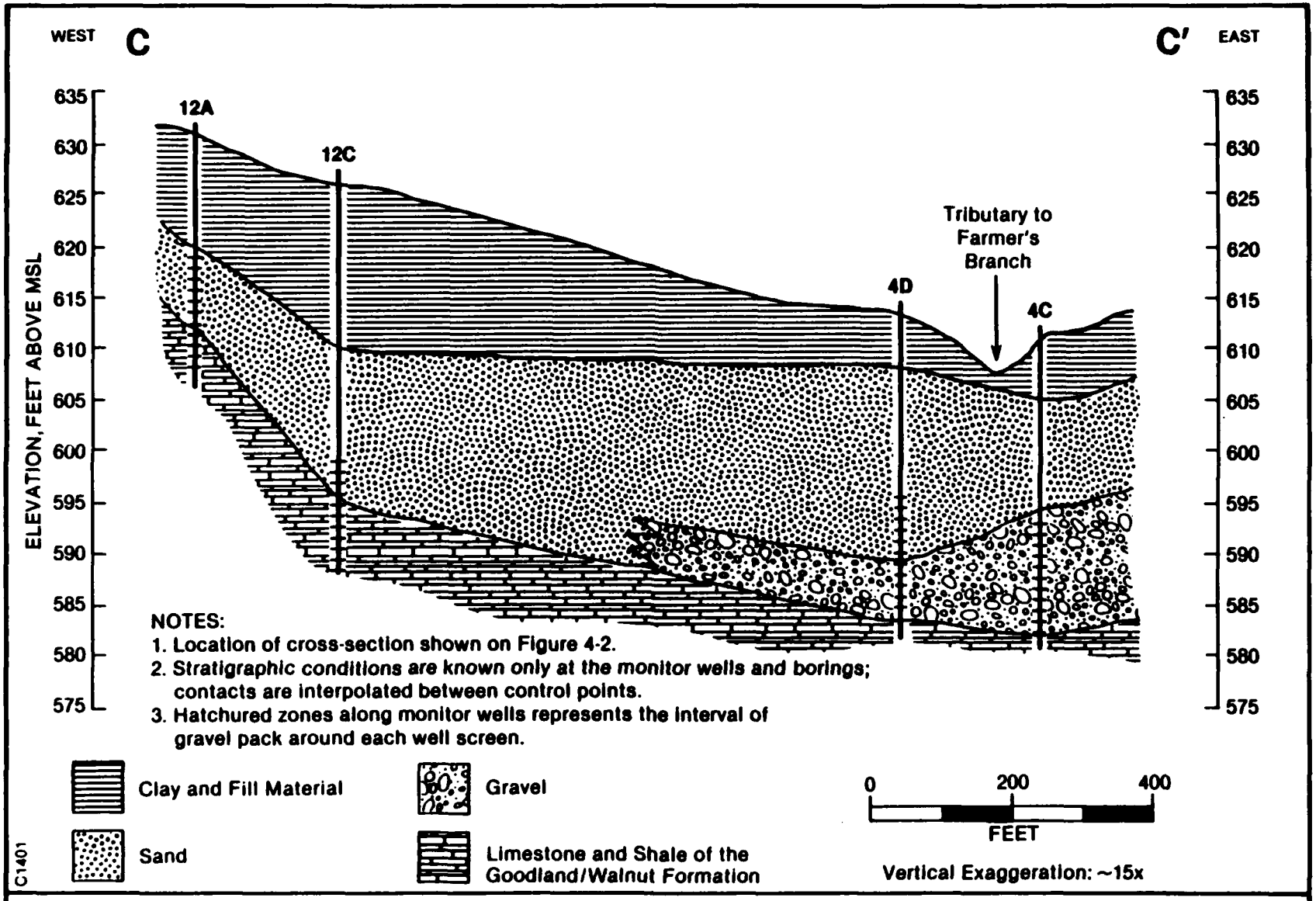

Figure 4-7. Geologic Cross-Section C-C', Carswell AFB, Texas.

Goodland and Walnut Formations and is composed of fine sand, with occasional lenses and layers of shale, lignite, and pyrite.

Geophysical Survey

Ground conductivity was read directly using the Geonics EM31 and EM34-3. By using both the EM31 and EM34-3, the apparent conductivities were measured with three different depths of investigation. The depth of investigation is approximately 10 feet with the EM31 (horizontal dipoles), 20 feet with the EM-31 (vertical dipoles), and approximately 50 feet with the EM34-3 with 20 meters of separation (see Section 3.1.1).

Data from the EMP surveys show numerous zones of high conductivity and rapid fluctuations in conductivity values. Figure 4-8 illustrates the conductivity values at Landfill 4 using the EM31 (horizontal dipoles). Buildings, telephone lines, and fences dominate the central portion of the grid and caused unreliable readings. In addition, high noise levels and variations in conductivity with time were noted throughout the grid. No definite trench or pit boundaries are apparent from the EMP data, although there are fairly consistent low conductivities on the west side of the grid indicating that this area is probably outside of the landfill. Locations 3 and 4 (Figure 4-8) also show coincident magnetic anamolies indicating the possibility of buried drums or other metallic wastes. Other anamolous areas on the north side of the grid are believed to be caused by metal structures in the vicinity of the radar installation.

The VES data (Appendix K) for Landfill 4 give several varied estimates for the thickness of the upper zone. Drilling data on the boundaries of the landfill show the upper zone thickness to be approximately 20 to 35 feet. The geophysical data are undoubtedly influenced by the presence of landfill material which may yield electrical responses different from natural materials encountered at the landfill perimeter during drilling operations.

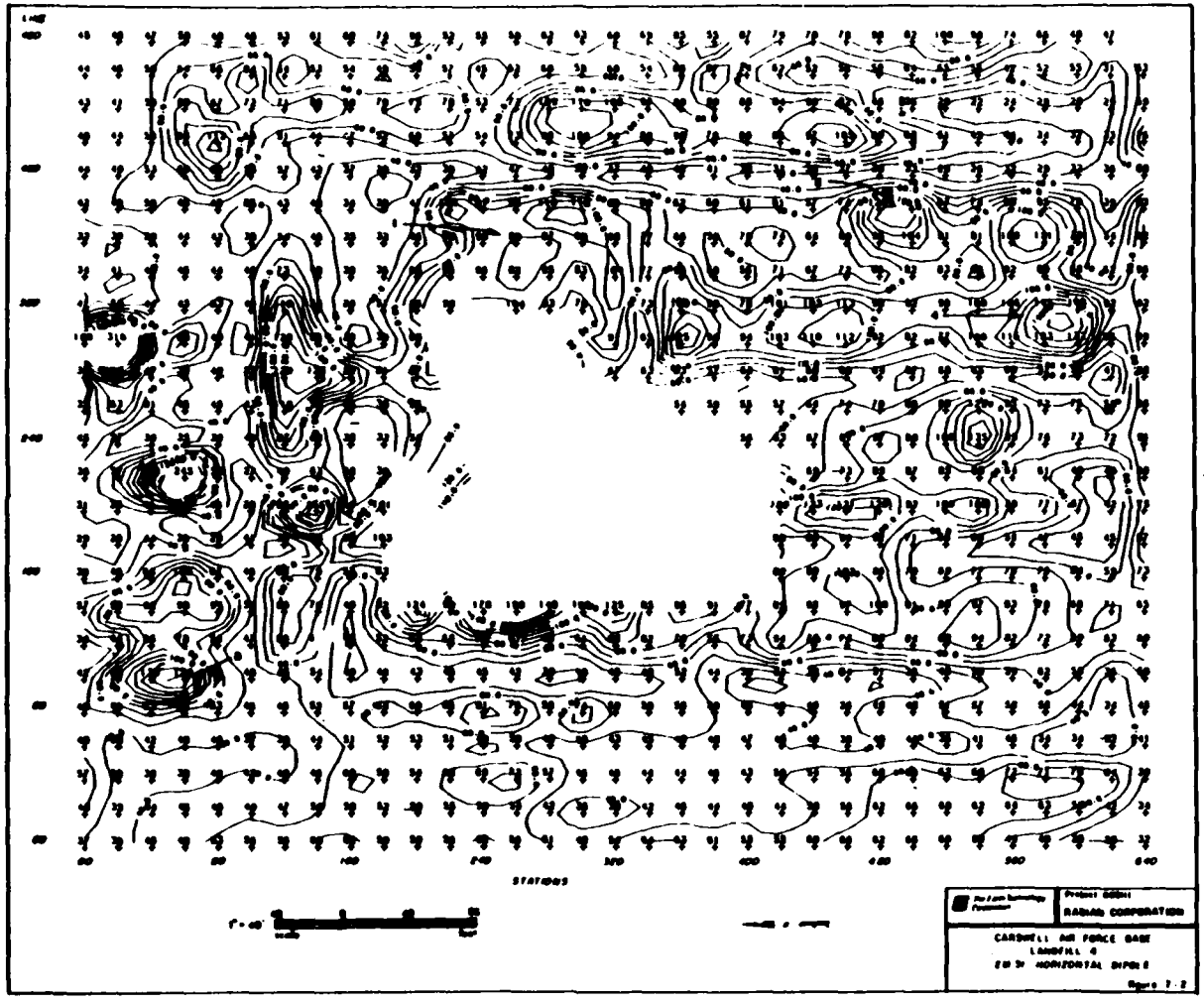

Figure 4-8. Electromagnetic Profile Data (EM31), Landfill 4, Carswell AFB, Texas.

Occurrence of Ground Water

Ground water occurs in the upper zone materials underlying Landfill 4 at depths ranging from approximately 10 feet at 4A to 23 feet at 4E. The ground water exists under unconfined (water table) conditions in both the upper zone materials and in the Paluxy aquifer. The depth to ground water in the Paluxy aquifer ranges from 73 feet at P2 to 80 feet at P1. The two ground water bodies are separated by the Goodland/Walnut aquitard.

Figure 4-5 illustrates the potentiometric surface of the water table as determined in March, 1985. Comparison of the potentiometric surface map for the upper zone ground water and the contour map of the base of the upper zone (Figure 4-3) strongly suggests that the occurrence and direction of movement of ground water in the upper zone are related to the configuration of the bedrock surface.

Ground water in the upper Paluxy Formation occurs under unconfined conditions at a depth of 73 feet below the land surface east of Landfill 4. The occurrence of unconfined conditions at the Flightline probably represents a local feature due to extensive pumping and resultant water level drawdown in White Settlement. The Paluxy aquifer is confined downdip and to the east. As part of the water quality sampling operations, a short-term aquifer test (pumping and recovery) was conducted at P2. The well is equipped with a submersible 1/3 horsepower electrical pump that produced a constant flow of 5 gallons per minute. The discharge rate and water level drawdown were measured during pumping and the recovery of the water level was measured after pumping stopped. Pump test and recovery test data are provided in Appendix F.

Recovery test data were analyzed for aquifer transmissivity by plotting the residual drawdown versus the ratio t/t' (t=time after pumping started, t'=time after pumping stopped). Figure 4-9 presents the recovery data and the graphical analysis which indicate that the transmissivity of the upper Paluxy is 1,970 gallons per day per foot. This value is consistent with

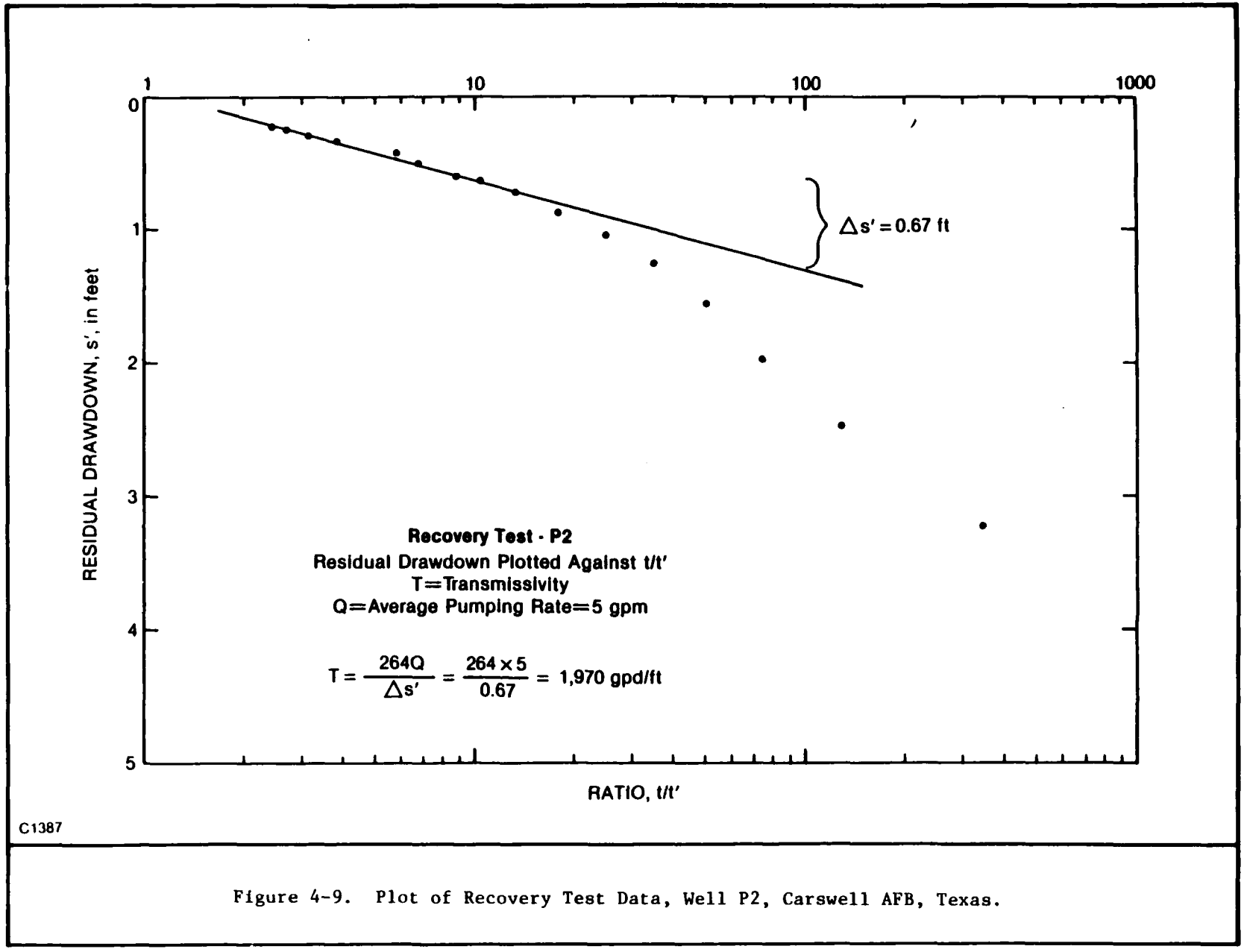

Figure 4-9. Plot of Recovery Test Data, Well P2, Carswell AFB, Texas.

results obtained for the upper Paluxy at P1 and in tests conducted at Air Force Plant 4 (Hargis & Associates, 1984).

Soil Chemistry and Water Quality

Split-spoon samples collected in the monitor well installation work were retained and visually examined for any evidence of contamination. Based on the depth and location of the samples, as well as the presence of water, samples of soil were selected for analysis of metals, oil and grease, and volatile organic compounds (Methods 601 and 602). The samples were selected for analysis such that the vertical and horizontal distribution of contamination could be evaluated. Results of the analyses are provided in Table 4-5.

After installation, each of the monitor wells was sampled for chemical analysis. A second round of sampling was conducted one month after the first sample set was collected. Results of the two sampling rounds are provided in Table 4-6. Surface water samples were also collected at one location just south of the landfill (Table 4-7). Samples were analyzed for metals, organic compounds, and purgeable and aromatic organic compounds. Complete reports of all analyses are provided in Appendix A. These data are discussed in the paragraphs below.

Heavy Metals Results of upper zone and Paluxy ground-water analyses for primary heavy metals at Landfill 4 indicate that the federal standards for drinking water (Table 4-1) are not exceeded. Furthermore, the data do not suggest any increased concentration trends relative to upgradient or downgradient locations. Likewise, most results of soil analyses do not suggest unusual concentrations of heavy metals in soils in comparison to typical values for soils (Table 4-3).

Organic Indicators Organic compounds (oil & grease, phenols, TOC) detected in ground water are generally in low concentrations. Although no excessive levels were detected, results from the February sampling event

TABLE 4-5. RESULTS OF SOIL SAMPLE ANALYSES, LANDFILL 4, CARSWELL AFB, TEXAS

Parameter	LOCATION[1] 4A (14-16 ft)	4B (14-16 ft)	4B (18-20 ft)	4C (18-20 ft)	4C (28-30 ft)	4D (18-20 ft)	4D (28-30 ft)	4E (24-26 ft)	4E (28-30 ft) (34-36 ft)
ORGANIC COMPOUNDS (ug/g)									
Phenol	<0.1	<0.1	<0.1 (<0.1, <0.1)	0.3	0.2	0.4	<0.15	0.4	0.3
METALS (ug/g)									
Arsenic	5.7	9.4	<5.2 (<5.1, <5.3)	8.5	5.9	<5.2	<5.7	<5.2	<5.4
Barium	18.0	80.0	36.5 (34.0, 39.0)	18.0	5.5	6.8	6.2	2.8	10
Cadmium	0.32	0.54	<0.17 (<0.17, <0.17)	0.64	0.42	<0.17	<0.18	<0.17	0.36
Chromium	1.7	2.0	1.45 (1.3, 1.6)	4.8	3.7	1.5	2.5	0.44	3.2
Mercury	<0.04	<0.04	<0.04 (<0.04, <0.04)	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Lead	7.8	7.5	<6.9 (<6.8, <7.0)	8.3	<6.3	<7.0	<7.6	<7.0	<7.2
Selenium	<0.1	<0.6	<6.9 (<6.8, <7.0)	<6.0	<6.3	<7.0	<7.6	<7.0	<7.2
Silver	2.0	1.4	0.73 (0.58, 0.88)	1.9	1.5	0.83	<0.19	0.21	0.68

[1] Duplicate field sample results are reported. The average of the two analytical values is shown first, followed by the actual values in parentheses "( )".

TABLE 4-6. RESULTS OF GROUND-WATER SAMPLE ANALYSES, LANDFILL 4, CARSWELL AFB, TEXAS

Parameter	MONITOR WELL[1] 4A Feb	4A Mar	4B Feb	4B Mar	4C Feb	4C Mar
METALS (mg/l)						
Arsenic - ICP	<0.06	<0.06 [<0.06, <0.06]	<0.06	<0.06	<0.06 [<0.06, <0.06]	<0.06
Barium	0.21	<0.065 [<0.060, 0.06]	0.4	0.67	0.40 [0.36, 0.43]	0.15
Cadmium	<0.002	<0.002 [<0.002, <0.002]	<0.002	<0.002	<0.002 [<0.002, <0.002]	<0.002
Chromium	<0.005	<0.005 [<0.005, <0.005]	<0.005	<0.005	<0.005 [<0.005, <0.005]	<0.005
Lead - ICP	<0.06	<0.06 [<0.06, <0.06]	<0.06	<0.06	<0.06 [<0.06, <0.06]	<0.06
Mercury	0.0024	<0.002 [<0.002, <0.002]	<0.005	<0.005	<0.009 [<0.009, <0.014]	<0.0002
Selenium - ICP	0.06	<0.06 [<0.06, <0.06]	<0.06	<0.[illegible]	<0.06 [<0.06, <0.06]	<0.06
Silver	<0.002	<0.002 [<0.002, <0.002]	<0.002	[illegible]02	<0.002 [<0.002, <0.002]	<0.002
METALS (mg/L) - AA (resampled November 1985)						
Arsenic		0.006		0.006		0.007
Lead		<0.002		<0.002		<0.002
Selenium		<0.003		<0.003		0.004
Mercury		0.0004		0.0003		0.0002
ORGANIC INDICATORS (mg/l)						
Oil & Grease	18	<1 [<1, <1]	<1	<1	21.5 [20, 23]	<1
Phenols	0.013	<0.005 [<0.005, <0.005]	0.008	<0.005	0.058 [0.1, 0.015]	<0.005
TOC	1	5 [8, 2]	1	8	8 [2, 16]	5
PESTICIDES/HERBICIDES (ug/L)	ND	ND	ND	ND	ND	ND
PURGEABLE HALOCARBONS[2] (ug/l)						
Vinyl Chloride	ND, ND	ND, ND	ND, ND	ND, ND	12.4 [12.3, 12.5]	ND, ND
Chloroethane	ND, ND	ND, ND	ND, ND	ND, ND	7.8 [7.8, 7.8]	7.3 [7.0, 7.5]
Methylene Chloride	ND, ND	ND, ND	4.2 [4.1, 4.3]	ND, ND	ND, ND	ND, ND
Trichlorofluoromethane	4.8 [5.8, 3.8]	4.5 [5.1, 3.8]	ND, ND	4.8 [5.1, 4.6]	3.3 [3.4, 3.2]	2.8 [2.8, 3.7]
1,1-Dichloroethene	3.3 [3.4, 3.1]	3.15 [3.1, 3.2]	ND, ND	ND, ND	2.6 [2.6, 2.5]	ND, ND
1,1-Dichloroethane	4.3 [4.4, 4.1]	ND, ND	ND, ND	ND, ND	ND, ND	[ND, 4.5]
1,1,1-Trichloroethane	8.1 [8.0, 8.2]	8.9 [8.2, 8.6]	3.15 [3.1, 3.2]	3.25 [3.2, 3.3]	25.1 [25.1, 25]	ND, ND
1,2-Dichloropropane	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
Trichloroethylene	3.0 [3.0, 3.0]	3.1 [3.1, 3.1]	ND, ND	1.8 [1.8, 1.8]	ND, ND	29.5 [29.1, 29.8]
Tetrachloroethylene	2.7 [2.7, 2.7]	ND, ND	ND, ND	ND, ND	15.7 [16.3, 15.1]	18.7 [18.5, 18.8]
Chlorobenzene	ND, ND	ND, ND	ND, ND	ND, ND	2.7 [2.68, 2.7]	ND, ND
1,4-Dichlorobenzene	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	8.0 [8.1, 8.8]
PURGEABLE AROMATICS[2] (ug/l)						
1,4-Dichlorobenzene	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	[5.5, ND]

[Continued]

TABLE 4-6. (Continued)

Parameter	MONITOR WELL[1] 4D Feb	4D Mar	4E Feb	4E Mar	PR Mar 7	PR Mar 28
METALS (mg/l)						
Arsenic - ICP	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Barium	0.44	0.15	0.41	0.084	0.084	0.089
Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Chromium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Lead - ICP	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Mercury	0.007	0.0006	<0.0005	<0.0002	<0.0002	0.0006
Selenium -ICP	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Silver	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
METALS (mg/L) - AA (resampled November 1985)						
Arsenic		<0.003		0.004		0.003
Lead		<0.002		<0.002		<0.002
Selenium		0.003		0.004		<0.003
ORGANIC INDICATORS (mg/l)						
Oil & Grease	<1	<1	<1	<1	<1	<1
Phenols	0.048	<0.005	0.009	<0.005	<0.005	0.02
TOC	2	28	6	5	<1	<1
PESTICIDES/HERBICIDES (ug/L)	ND	ND	ND	ND	ND	ND
PURGEABLE HALOCARBONS[2] (ug/l)						
Vinyl Chloride	7.1 (7.2, 6.9)	ND, ND	ND, ND	ND, ND	ND	ND
Chloroethane	ND, ND	ND, ND	ND, ND	ND, ND	ND	ND
Methylene Chloride	ND, ND	ND, ND	ND, ND	ND, ND	ND	ND
Trichlorofluoromethane	3.5 (3.5, 3.4)	ND, ND	ND, ND	ND, ND	ND	ND
1,1-Dichloroethene	8.1 (7.9, 8.1)	ND, ND	ND, ND	ND, ND	ND	ND
1,1-Dichloroethane	ND, ND	ND, ND	ND, ND	ND, ND	ND	ND
1,1,1-Trichloroethane	ND, ND	ND, ND	ND, ND	ND, ND	ND	ND
1,2-Dichloropropane	2.3 (2.3, 2.3)	ND, ND	ND, ND	ND, ND	ND	ND
Trichloroethylene	3345 (3410, 3280)	3100 (3060, 3140)	3935 (3360, 4250)	4175 (3800, 4550)	ND	ND
Tetrachloroethylene	ND, ND	ND, ND	ND, ND	ND, ND	ND	ND
Chlorobenzene	2.6 (3.5, 3.7)	ND, ND	ND, ND	ND, ND	ND	ND
1,4-Dichlorobenzene	ND, ND	ND, ND	ND, ND	ND, ND	ND	ND
PURGEABLE AROMATICS[2] (ug/l)						
1,4-Dichlorobenzene	ND, ND	ND, ND	ND, ND	ND[3], ND[3]	ND	ND

[1] Duplicate field sample results are reported. The average of the two analytical values is shown first followed by the actual values used in parenthesis "( )".

[2] Parameters shown were detected (ND = not detected.)

[3] Method 602 run at 0.01 dilution due to non-602 compound interference.

TABLE 4-7. RESULTS OF SURFACE-WATER SAMPLE ANALYSES, LANDFILL 4, CARSWELL AFB, TEXAS

Parameter	January	February
ORGANIC INDICATORS (mg/L)		
COD	4	<1
TOC	2	3
PESTICIDES/HERBICIDES (ug/L)	ND	ND
PURGEABLE HALOCARBONS (ug/L)		
Vinyl Chloride	2.3	ND
Methylene Chloride	2.7	ND
1,1,1-Trichloroethane	ND	5.0
Trichloroethylene	1.4	4.3
PURGEABLE AROMATICS (ug/L)	ND	ND

Note: Parameters shown were detected (ND = not detected).

indicated the presence of relatively high values of oil & grease in wells 4A and 4C. However, these wells had low concentrations of these compounds in March. In addition, a relatively elevated reading of TOC was observed in water collected at well 4D in March. Samples collected from the stream south of the landfill also had low values of organic indicators (e.g., COD: <1-4 mg/L; TOC:2-3 mg/L). Insecticides and herbicides were analyzed, but not detected, in water samples.

Purgeable Halocarbons Purgeable halocarbons were detected in every monitor well at Landfill 4. The range of concentrations was wide, with most results showing less than 10 ug/L. In general, ground water from wells 4A and 4B had detectable amounts, but no excessive concentrations of a variety of purgeable halocarbons. However, ground water from monitor wells 4C, 4D, and 4E contained purgeable halocarbons, principally TCE ranging from not detected to 4,550 ug/L. Concentrations of greater than 3,000 ug/L TCE were consistently detected at wells 4D and 4E. Tetrachloroethylene was also detected in levels greater than 10 ug/L at well 4C.

Small amounts (less than 5 ug/L) of purgeable halocarbons were detected in the stream samples. Purgeable halocarbons were not detected in the Paluxy aquifer or soil at Landfill 4.

Purgeable Aromatics In general, purgeable aromatic compounds were not detected in surface water, ground water, or soil at Landfill 4. However, less than 10 ug/L of 1, 4-dichlorobenzene was detected at well 4C during the March sampling event.

Significance of Findings

Results of analyses of ground water at the five upper zone monitor wells indicates that the upper zone water has levels of volatile organic compounds (principally TCE) that exceed EPA drinking water guidelines downgradient (east) of the landfill. Figure 4-10 illustrates the areal distribution of

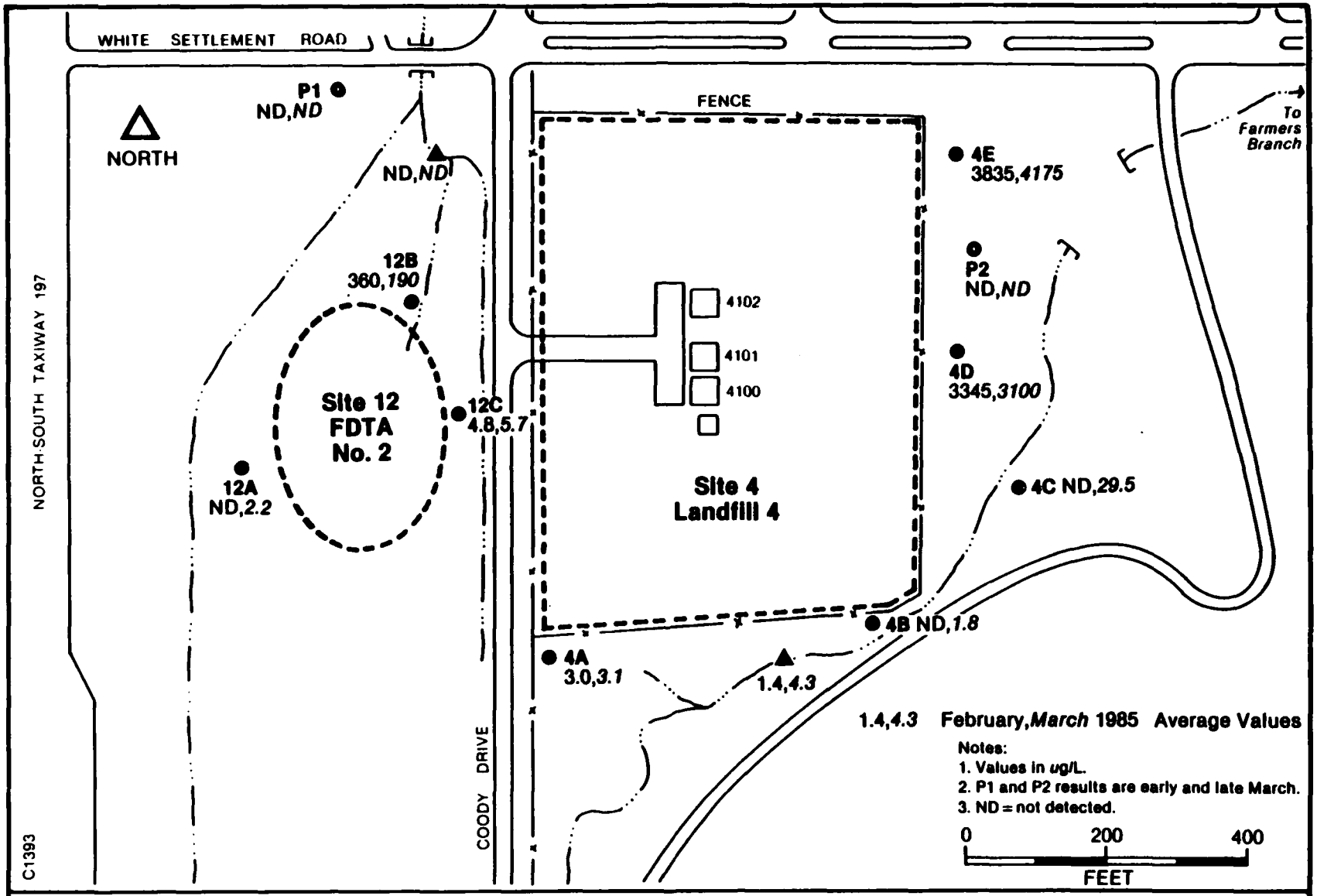

Figure 4-10. Areal Distribution of TCE in Water, Landfill No. 4 (Site 4) and Fire Department Training Area No. 2 (Site 12), Carswell AFB, Texas.

TCE as determined from sampling and analysis at Landfill 4 and Fire Training Area 2. Wells 4A and 4B, hydraulically upgradient of the site, show very low levels (less than 10 ug/L) of a variety of volatile organic compounds and do not suggest significant ground water contamination relative to other areas of the flightline. However, significant amounts of TCE were detected at wells 4D and 4E, just east of the site. At well 4C, separated from Landfill 4 by a dry tributary to Farmers Branch, a variety of VOCs were detected. Concentrations of VOC at well 4C are intermediate to those detected at wells 4A, 4B, and wells 4D and 4E. The flow patterns of the upper zone ground water, as determined by the potentiometric surface contour map in Figure 4-5, indicates that ground water flowlines under the landfill would not intersect well 4C. The observation that the small stream contributes water to the upper zone deposits near well 4C suggests that the surface water may exert some influence on the quality of ground water at well 4C.

The levels of TCE in the upper zone at wells 4D and 4E range from 3,060 to 4,550 ug/L. Considered alone, these data suggest that the source of the TCE is at Landfill 4. This landfill is known to have consisted of pits where waste liquids, and presumably solvents, were burned and/or buried. The analytical results are consistent with the information about the types of wastes handled at the pits. However, the discovery of similar levels of TCE in the upper zone at widely separated locations in the flightline area suggests other sources may also be responsible for elevated levels of TCE.

Analytical results of metals and organic indicator parameters are within typical ranges for ground water. Similarly, the results of the soil analyses are within typical "background" levels and do not suggest a source of contamination within the soil or residual contamination in the soil. These data would point to an upgradient source for the ground water contamination rather than a source directly above the wells. This is because contamination will first move in vertical direction under the influence of gravity in the unsaturated zone, then when the ground water table is encountered, the body of

contaminants will then be entrained with the ground water flow in a downgradient direction.

Samples of ground water collected from well P2, screened in the upper sand unit of the Paluxy Formation, do not reveal the presence of volatile organic compounds. It can be concluded on the basis of these data that contaminants from the upper zone have not affected the Paluxy aquifer downgradient of Landfill 4. In addition, it can be concluded that the methods used to prevent cross-contamination of ground water during drilling operations were successful.

4.2.1.2 Landfill 5 (Site 5)

Work performed at Landfill 5 consisted of geophysical (EMP, VES) surveys, installation of upper zone monitor wells, installation of a Paluxy monitor well, and collection of surface-water samples. The results of the hydrogeologic, geophysical, and chemical data are discussed in the following paragraphs. Figure 4-11 illustrates the locations and limits of the geophysical surveys, monitor wells, and surface water sampling points.

Topography

Landfill 5 is located in the southern part of Carswell AFB just north of the intersection of White Settlement Road and Coody Drive on land ranging in elevation from 620 to 595 feet msl. The disposal area is visible as a slightly elevated and hummocky surface. Surface drainage is generally to the north to an unnamed tributary of Farmers Branch.

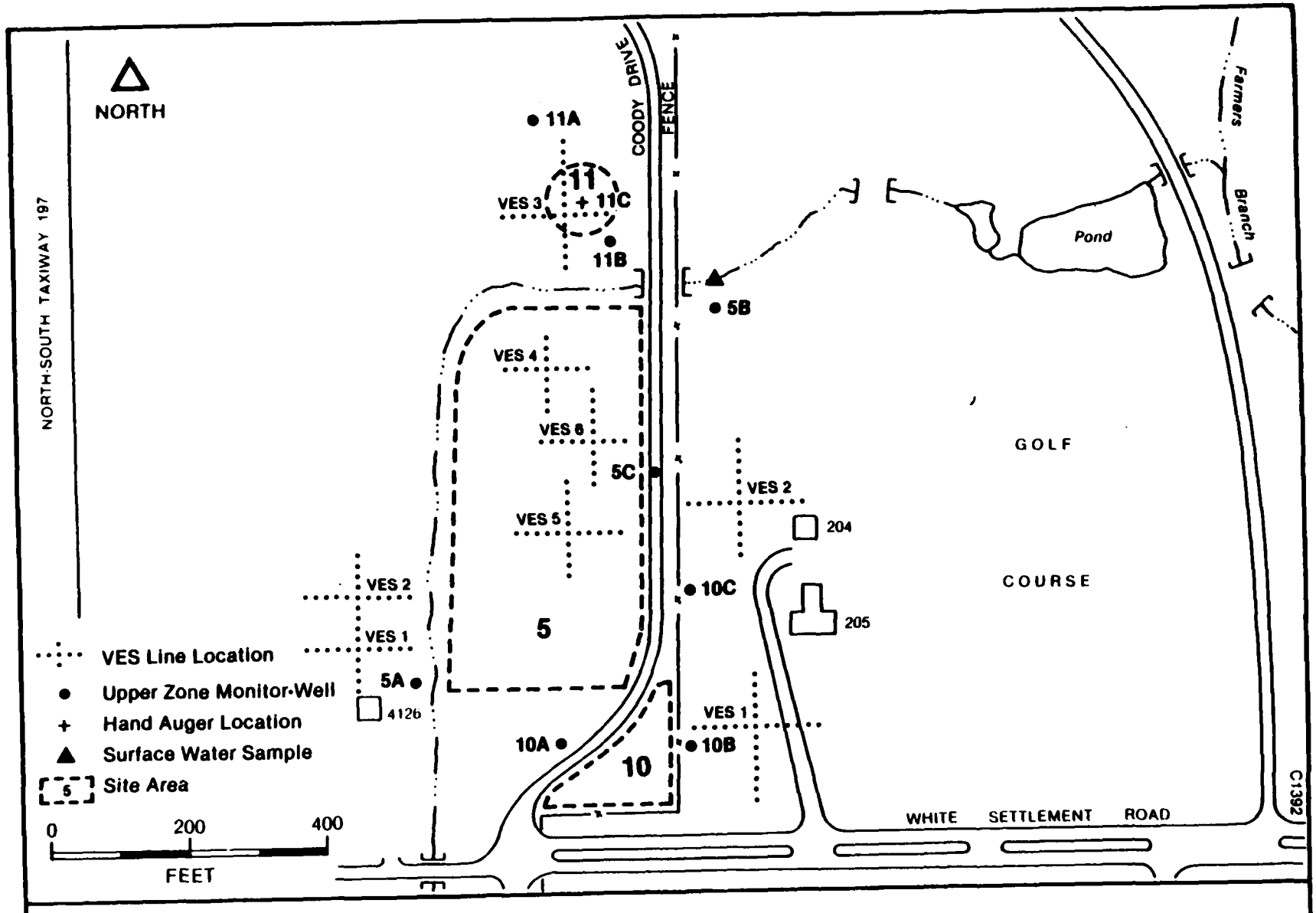

Figure 4-11. Detail of Monitoring Locations, Landfill No. 5 (Site 5), Waste Burial Area (Site 10) and Fire Department Training Area No. 1 (Site 11), Carswell AFB, Texas.

Geologic Features

Geologic data developed for Landfill 5 resulted from three activities: geophysical surveys (EMP and VES), geologic sampling during drilling operations, and observations of water levels during and after monitor well installation.

The geologic picture at Landfill 5 is based on an evaluation of drilling logs developed during the installation of three upper zone monitor wells and one Paluxy monitor well. Data obtained from other nearby upper zone monitor wells installed at the Waste Burial Area (Site 10) were also useful in the interpretation of geologic conditions at the landfill. Upper zone materials consist of surficial deposits of clayey silt with variable amounts of fine sand and gravel, in turn underlain by sand and gravel deposits. The thickness of the upper zone ranges from 5 feet at monitor well 5B to 34 feet at monitor well 5A. The surficial clay and silt deposits are 5 to 10 feet thick and the sand and gravel deposits are 10 to 30 feet thick. It was observed that in most borings the grain size of the sand and gravel increases with depth.

Shale and limestone of the Goodland Formation underlie the upper zone materials at all locations. The top of the Goodland occurs at a maximum depth of 34 feet in the southwest corner of the site (at 5A) and at its shallowest depth of 8 feet in the north (at 5B). The bedrock/upper zone contact is generally flat under Landfill 5, in contrast to the pronounced slope to the south under Landfill 4. Figure 4-3 illustrates the contact relationship between the upper zone materials and the underlying limestone and shale.

Drilling at P1, just south of the landfill, revealed that the Goodland and Walnut Formations are 30 feet thick. The thickness of these formations varies with the position of the eroded upper surface of the Goodland limestone. The Paluxy Formation underlies the Goodland and Walnut Formations and is composed of fine sand containing lignite and pyrite and interbedded with occasional lenses and layers of shale.

Geophysical Surveys

Ground conductivity was read directly using the Geonics EM31 and EM34-3, allowing the measurement of apparent conductivities with three different depths of investigation. The depth of investigation is approximately 10 feet with the EM-31 (horizontal dipoles), approximately 20 feet with the EM-31 (vertical dipoles), and approximately 50 feet with the EM34-3 with 20 meters of separation (see Section 3.1.1).

Ground conductivity data from the EM31 (horizontal) is plotted on Figure 4-12. The dominant linear-shaped high conductivity feature west of the landfill is suspected to be a clay berm built on the edge of the landfill bordering the creek. There is no surface expression of the berm. A marked increase in conductivity is seen throughout the area east of this berm and south of the creek, suggesting landfill materials having a greater conductivity than natural geologic materials. The landfill boundaries, as defined by the EMP data are: the subsurface berm to the west, the creek to the north, and line 00 to the south.

The VES data reveal a layered subsurface that is basically consistent with the geologic model developed from boring data. A particularly good agreement of VES and boring data occur at the center of the landfill where the thickness of the upper zone is approximately 30 feet.

Occurrence of Ground Water

Ground water occurs in the upper zone materials in the vicinity of Landfill 5 at depths ranging from less than 2 feet at 5B to 22 feet at 5A. The ground water exists under unconfined (water table) conditions in both the upper zone materials and in the Paluxy aquifer. The depth to ground water in the Paluxy aquifer ranges from 73 feet at P2 to 80 feet at P1. The two ground water bodies are separated by the Goodland/Walnut aquitard.

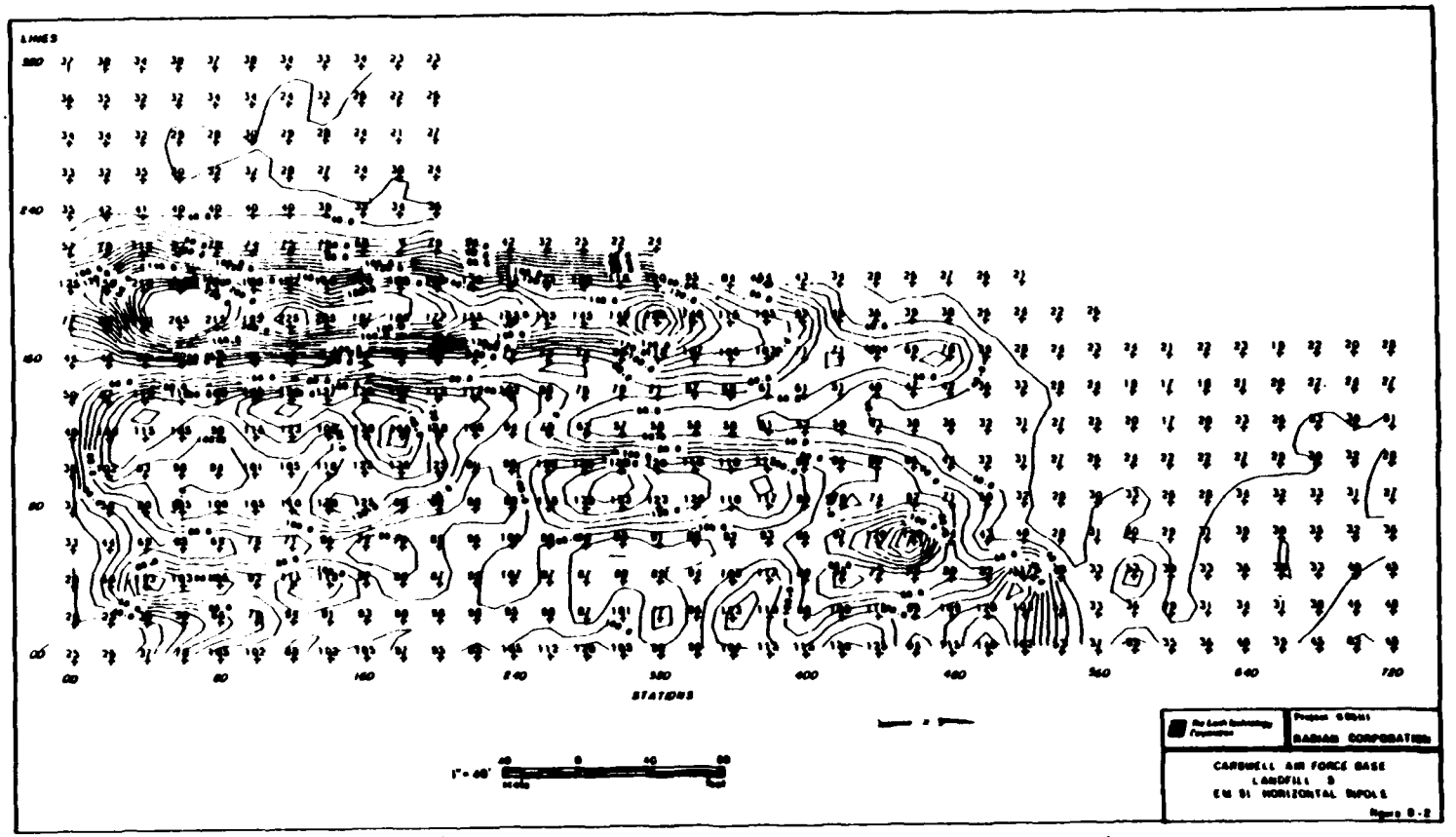

Figure 4-12. Electromagnetic Profile Data (EM31), Landfill No. 5 (Site 5) and Fire Department Training Area No. 1 (Site 11), Carswell AFB, Texas.

Figure 4-5 illustrates the potentiometric surface of the water table as determined in March, 1985. Hydraulic head in the upper zone decreases slightly to the east, indicating that ground-water flow is to the east under a hydraulic gradient of 0.0003. Comparison of the potentiometric surface map for the upper zone ground water and the contour map of the base of the upper zone (Figure 4-3) strongly suggests that the occurrence and direction of movement of ground water in the upper zone is directly related to the configuration of the bedrock surface.

Ground water in the upper Paluxy Formation occurs under unconfined conditions at a depth of 80 feet below the land surface south of Landfill 5. As part of the water quality sampling operations, a short-term aquifer test (pumping and recovery) was conducted at P1. The well is equipped with a submersible 1/3 horsepower electrical pump that produced a constant flow of 5 gallons per minute. The discharge rate and water level drawdown were measured during pumping and the recovery of the water level was measured after pumping stopped. Pump test and recovery test data are provided in Appendix F.

Recovery test data were analyzed for aquifer transmissivity by plotting the residual drawdown versus the ratio t/t' (t=time after pumping started, t'= time after pumping stopped). Figure 4-13 presents the recovery data and the graphical analyses developed by Cooper and Jacob (1946). Results of the recovery test analysis indicate that the transmissivity of the upper Paluxy is 1,535 gallons per day per foot. This value is consistent with results obtained for the upper Paluxy at P2 and in tests conducted at AF Plant 4 (Hargis & Associates, 1984).

Soil Chemistry and Water Quality

Split-spoon samples collected in the monitor well installation work were retained and visually examined for any evidence of contamination. Based on the depth and location of the samples, as well as the presence of water, samples of soil were selected for analysis of metals, oil and grease, and

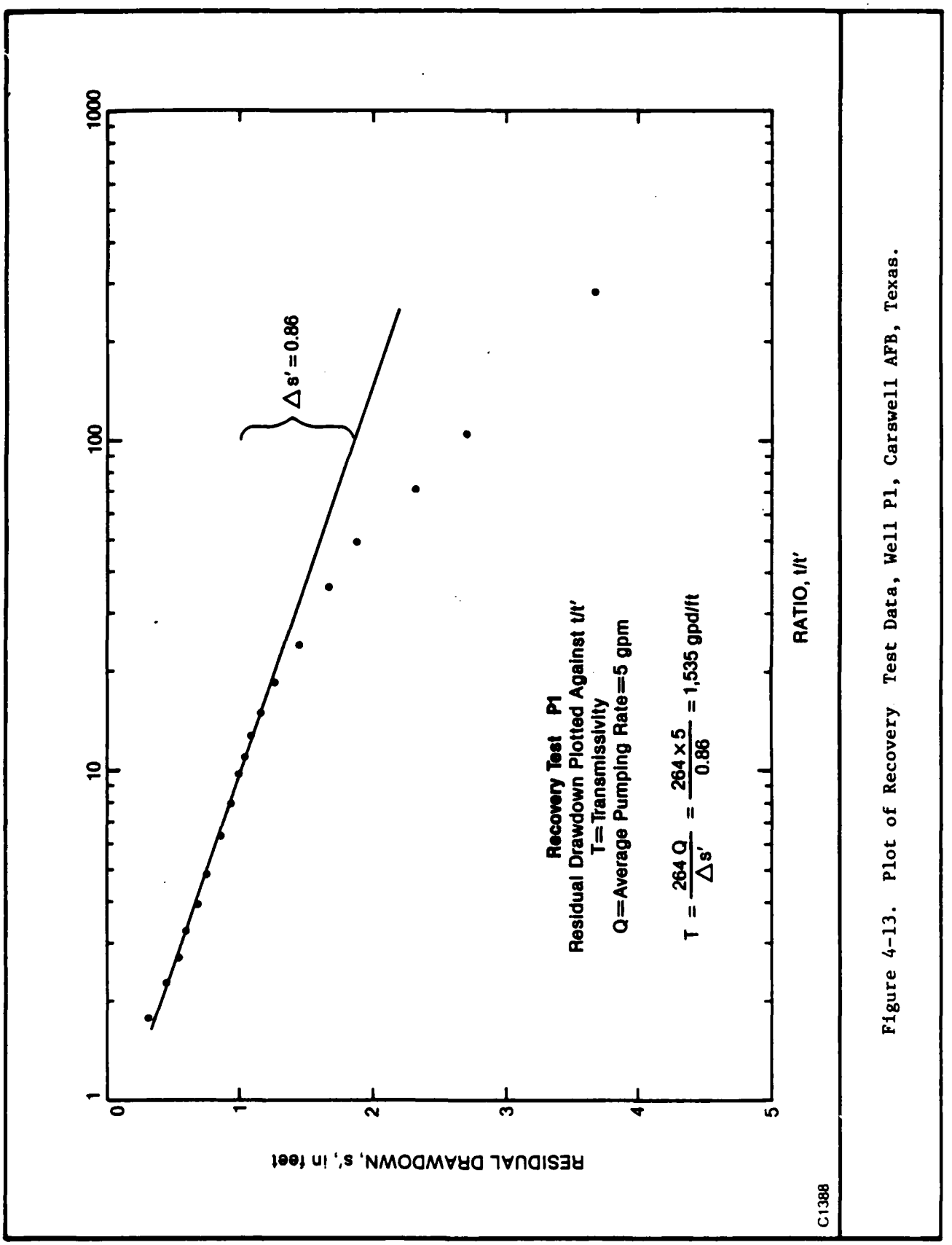

Figure 4-13. Plot of Recovery Test Data, Well P1, Carswell AFB, Texas.

volatile organic compounds (Methods 601 and 602). The samples were selected for analysis such that the vertical and horizontal distribution of contamination could be evaluated. Results of the analyses are provided on Table 4-8.

After installation, each of the monitor wells was sampled for chemical analysis. A second round of sampling was conducted one month after the first sample set was collected. Results of the two sampling rounds are provided in Table 4-9. Surface water samples (Table 4-10) were also collected at one location just south of the landfill. Samples were analyzed for metals, organic compounds, (oil and grease, TDC and TOX) and purgeable and aromatic organic compounds. Complete reports of all analyses are provided in Appendix A. These data are discussed below.

Heavy Metals Concentrations of heavy metals in ground water were determined to be less than the federal standards for drinking water (Table 4-1). There appear to be no trends in the concentrations of metals relative to upgradient or downgradient positions of the monitor wells. Likewise, results of soil analyses indicate that the metals contents of the soil are within expected limits for natural soils (Table 4-3).

Organic Indicators Values of oil and grease, phenols, TOC, and TOX are generally within expected limits for water and soil. In surface water and ground water, it was observed that oil and grease values for February were noticably higher than the March values. However, there appeared to be no similar phenomena in other parameters for the same time period. Results of soil analyses for organic indicator parameters indicate background levels.

Purgeable Halocarbons Purgeable halocarbons, principally TCE, were detected in ground water in the vicinity of Landfill 5. Interestingly, values of TCE were greatest in the upgradient well (5A) and lowest in the downgradient well (5B). Values of TCE ranged from less than 10 ug/L at 5B to 3,200 ug/L at 5A, both in February. The other major purgeable halocarbon detected

TABLE 4-8. RESULTS OF SOIL SAMPLE ANALYSES, LANDFILL 5, CARSWELL AFB, TEXAS

Parameter	LOCATION 5A (24-25 ft)	5A (29-30 ft)	5B (4-5 ft)	5C (14-15 ft)	5C (19-20 ft)
METALS (ug/g)					
Arsenic	7.1	<5.8	<5.9	8.4	<5.9
Barium	2.8	19	70	13	4.4
Cadmium	0.47	<0.19	0.38	0.62	<0.20
Chromium	2.0	4.1	47	3.7	0.74
Lead	<7.8	<7.8	<7.9	8.4	<7.9
Mercury	0.09	0.09	0.21	0.08	<0.05
Selenium	<7.8	<7.8	<7.9	<7.7	<7.8
Silver	<0.20	1.0	0.45	0.54	<0.20
ORGANIC INDICATORS (ug/g)					
Oil & Grease	<10	10	<10	<10	<10
Phenols	0.3	<0.1	<0.1	<0.1	<0.1
PURGEABLE HALOCARBONS[1] (ug/g)					
Trans-1,2-Dichloroethene	0.024	ND	ND	0.033	0.015
Trichloroethylene	0.287	0.257	ND	0.338	0.277
PURGEABLE AROMATICS[1] (ug/g)					
Ethyl Benzene	ND	ND	ND	ND	1.070
Toluene	ND	ND	ND	0.460	ND

[1] Parameters shown were detected (ND = not detected).

TABLE 4-9. RESULTS OF GROUND-WATER SAMPLE ANALYSES, LANDFILL 5, CARSWELL AFB, TEXAS

Parameter	MONITOR WELL[1] 5A Feb	5A Mar	5B Feb	5B Mar	5C Feb	5C Mar	P1 Mar 7	P1 Mar 88
METALS (mg/L)								
Arsenic - ICP	<0.00 [<0.00, <0.00]	<0.00	<0.00	<0.00	<0.00	<0.00 [<0.00, <0.00]	<0.00	<0.00
Barium	0.105 [0.10, 0.10]	0.11	0.00	0.00	0.00	0.10 [0.10, 0.10]	0.000	0.000
Cadmium	<0.000 [<0.000, <0.000]	<0.000	<0.000	<0.000	<0.000	<0.000 [<0.000, <0.000]	<0.000	<0.000
Chromium	<0.000 [<0.000, <0.000]	<0.000	<0.000	<0.000	<0.000	<0.000 [<0.000, <0.000]	<0.000	<0.000
Lead - ICP	<0.00 [<0.00, <0.00]	<0.00	<0.00	<0.00	<0.00	<0.00 [<0.00, <0.00]	<0.00	<0.00
Mercury	0.000 [0.007, <0.000]	<0.0000	<0.0000	<0.000	<0.000	<0.0000 [<0.0000, <0.0000]	0.0004	0.0000
Selenium - ICP	<0.00 [<0.00, <0.00]	<0.00	<0.00	<0.00	<0.00	<0.00 [<0.00, <0.00]	<0.00	<0.00
Silver	<0.000 [<0.000, <0.000]	<0.000	<0.000	<0.000	<0.000	<0.000 [<0.000, <0.000]	<0.000	<0.000
METALS (mg/L) - AA (resampled November 1985)								
Arsenic		0.000		0.010		0.000		<0.000
Lead		<0.000		<0.000		<0.000		<0.000
Selenium		0.000		<0.000		<0.000		<0.000
ORGANIC INDICATORS (mg/L)								
Oil & Grease	61 [60, 40]	<1 [<1, <1]	210 [200, 210]	<1	45	<1, <1	<1	<1
Phenols	0.000 [0.075, 0.000]	<0.000	0.000	<0.000	0.012	<0.000 [<0.000, <0.000]	<0.000	<0.000
TOC	1.0 [1, 2]	1	0	0	4	2, 2	<1	<1
TOX	[0.00, 1.0]	1.1 [0.00, 1.4]	0.000 [0.04, 0.00]	0.02	1.0	[1.0, 0.00]	<0.01	<0.01
PURGEABLE HALOCARBONS[2] (ug/L)								
Vinyl Chloride	ND, ND	ND, ND	101.0 [100, 100]	171.0 [100, 170]	ND, ND	ND, ND	ND	ND
Chloroethane	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	ND	ND
Methylene Chloride	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	ND	ND
Trichlorofluoromethane	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	ND	ND
1,1-Dichloroethene	ND, ND	ND, ND	[7.0, ND]	ND, ND	ND, ND	ND, ND	ND	ND
1,1-Dichloroethane	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	ND	ND
1,1,1-Trichloroethane	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	ND	ND
1,2-Dichloropropane	ND, ND	ND, ND	[2.0, ND]	ND, ND	ND, ND	ND, ND	ND	ND
Trichloroethene	3040 [3000, 3000]	3040 [2700, 3100]	[0.0, ND]	30.4 [30.0, 27.1]	1700 [1700, 1700]	2100 [2000, 1900]	ND	ND
Tetrachloroethylene	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	ND	ND
Chlorobenzene	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	ND	ND
PURGEABLE AROMATICS[2] (ug/L)	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	ND	ND

[1] Duplicate field sample results are reported. The average of the two analytical values is shown first, followed by the actual values used in parenthesis "[ ]".

[2] Parameters shown were detected; other parameters not listed were scanned but not detected.

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TABLE 4-10. RESULTS OF SURFACE-WATER SAMPLE ANALYSES, LANDFILL 5, CARSWELL AFB, TEXAS

Parameter	January	February
ORGANIC INDICATORS (mg/L)		
Oil & Grease	350	<1
TOC	8	12
COD	5	9
PESTICIDES/HERBICIDES (ug/L)[1]	NA	ND
PURGEABLE HALOCARBONS (ug/L)[2]		
Vinyl Chloride	ND	38.7
trans-1,2-Dichloroethene	ND	56.9
Trichloroethylene	ND	4.4
PURGEABLE AROMATICS (ug/L)	ND	ND

Notes: [1]Sample container broken during shipment. (NA = not analyzed).
[2]ND = not detected.

in significant levels was vinyl chloride, observed in monitor well 5B ranging from 128 ug/L to 178 ug/L. These results are also similar to the analytical results obtained from the February surface water sample collected in the vicinity of well 5B. This surface water sampled contained 38.7 ug/L vinyl chloride and 56.9 ug/L trans-1,2-dichloroethene.

Levels of TCE in soils ranged from 0.257 ug/g to 0.338 ug/g in borings 5A and 5C. The findings of TCE in soil at these locations is consistent with the results of the ground-water quality analyses. Trans 1,2-dichloroethene was also detected in the soil samples collected from borings 5A and 5C. Purgeable halocarbons were not detected in the water sample collected from boring 5B.

Purgeable Aromatics Ground-water analyses revealed no purgeable aromatic compounds at Landfill 5. However, soil samples from boring 5C had significant levels of toluene and ethyl benzene. Toluene was detected at the 14-15 foot depth at 0.46 ug/g; ethyl benzene was detected at the 19-20 foot depth at 1.07 ug/g. These levels of purgeable aromatics are consistent with the observed levels of oil and grease.

Significance of Findings

Results of soil and ground water sampling conducted at Landfill 5 indicate that the upper zone contains elevated levels of halogenated organic compounds. Figure 4-14 illustrates the areal distribution of TCE, the principal contaminant observed in the upper zone at Landfill 5 and the Waste Burial Area. Several soil samples corresponding to the occurrence of ground water during drilling contained volatile organic compounds. Soil in the saturated zone at well 5A, hydraulically upgradient of the landfill, contained high levels of trichloroethene. Similarly, samples collected at well 5C, both in the unsaturated and saturated zone, indicate contamination with trans-1,2-dichloroethene and trichloroethene, as well as levels of the aromatic compounds

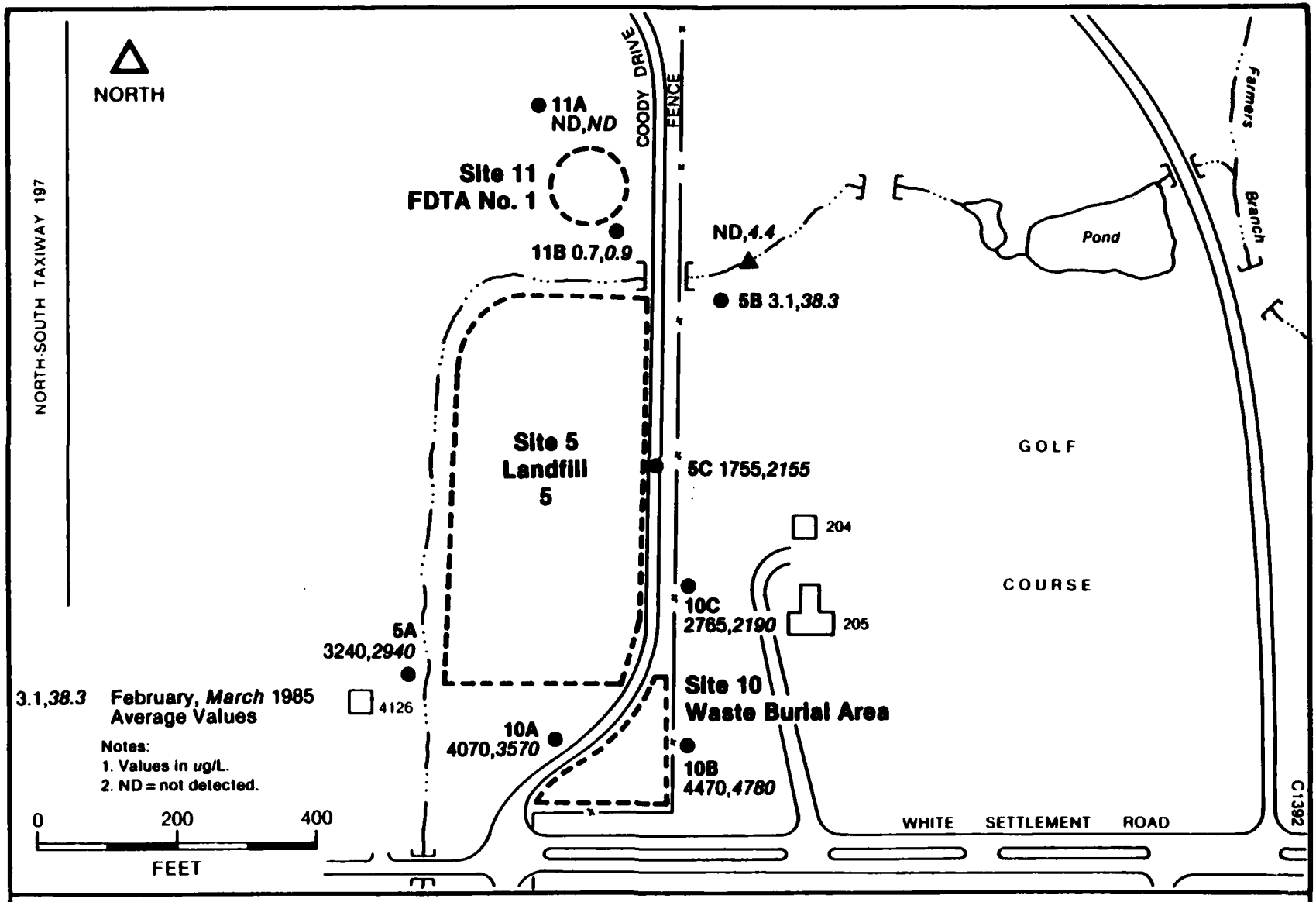

Figure 4-14. Areal Distribution of TCE; Landfill No. 5 (Site 5), Waste Burial Area (Site 10) and Fire Department Training Area No. 1 (Site 11), Carswell AFB, Texas.

ethyl benzene and toluene. Results of metals analyses and other organic parameters showed essentially background levels.

Ground water at Landfill 5 has elevated levels of TCE, detected in amounts of 2,730 to 3,280 ug/L at well 5A and 1,750 to 2,330 ug/L at well 5C. The finding of TCE in ground water upgradient of the landfill indicates that the landfill is not a sole contributor of contamination to the upper zone ground water. In addition, results of analyses from well 5B, which monitors a thin section of upper zone adjacent to the unnamed tributary to Farmers Branch are very similar to results obtained at the surface water sampling point. The significant finding consisted of elevated levels of vinyl chloride, with somewhat smaller levels of TCE. During sampling, the water level in the stream closely corresponds to the elevation of the ground water table, suggesting that the stream is effluent (ground water contributes to the base flow of the stream), a reverse of the phenomenon observed in another tributary to Farmers Branch, just south of Landfill 4. The ground-water and surface water relationships appear to be largely controlled by the thickness of the upper zone deposits. Thin, permeable deposits are recharged by streamflow south of Landfill 4 and the thin, less permeable deposits contribute ground water to the base flow of the small stream north of Landfill 5.

Contaminants in the upper zone ground water would be expected to migrate downgradient to the east in the direction of ground water flow. Ground water moving toward Farmers Branch and the Trinity River can be discharged to the surface in streams or seeps. The available data suggest, but do not confirm, that ground water at Landfill 5 will move to the east and be eventually discharged at Farmers Branch or the Trinity River.

4.2.1.3 Waste Burial Area (Site 10)

Work performed at the Waste Burial Area consisted of geophysical (EMP, VES) surveys and the installation of upper zone monitor wells. The

results of the hydrogeologic, geophysical, and chemical data are discussed in the following paragraphs. Figure 4-11 illustrates the locations and limits of the geophysical surveys and monitor wells.

Topography

The Waste Burial Area is located in the southern part of Carswell AFB at the northeast corner of the intersection of White Settlement Road and Coody Drive. The land surface is virtually flat at an approximate elevation of 620 feet msl. There is no visible evidence of the boundaries of the disposal area, although a warning sign marks the apparent center of the area. Surface drainage is generally to the north to an unnamed tributary of Farmers Branch.

Geologic Features

Geologic data developed for the Waste Burial Area resulted from three activities: geophysical surveys (EMP and VES), geologic sampling during drilling operations, and observations of water levels during and after monitor well installation.

The geologic picture at the Waste Burial Area is based on an evaluation of drilling logs developed during the installation of three upper zone monitor wells. Results of drilling at Site 10 are consistent with the data obtained at other Flightline area borings. Upper zone materials consist of surficial deposits of clayey silt with variable amounts of fine sand and gravel, in turn underlain by sand and gravel deposits. The thickness of the upper zone ranges from 30 feet at monitor well 10C to greater than 39 feet at monitor well 10A. Generally, the surficial clay and silt deposits are 7 to 12 feet thick and the sand and gravel deposits are 19 to greater than 27 feet thick. It was observed that in most borings in the vicinity of the flightline, the grain size of the sand and gravel increases with depth. Coarse

gravel and cobbles were encountered in all borings at the base of the upper zone.

Shale and limestone of the Goodland Formation underlie the upper zone materials at all locations. The top of the Goodland occurs at a maximum depth of greater than 39 feet west of the site (at 10A) and at its shallowest depth of 30 feet northeast of the site (at 10C). The contact between the bedrock and the upper zone is generally flat, in contrast to the pronounced slope to the south under Landfill 4. A slight bedrock high exists in the vicinity of boring 10B (Figure 4-3).

Geophysical Survey

Ground conductivity was read directly using the Geonics EM31 and EM34-3 according to the same techniques employed at the other Flightline area sites.

The EMP data for Site 10 reveal that background values of conductivities are similar to the results at other flightline area sites. However, several areas of anomalous conductivity occur at the site (see Appendix K for geophysical data). The anomaly along line 00 (Figure 3-5) is believed to be associated with an underground water pipeline. The anomaly at L60/-50 has no visible cultural source and corresponds to a magnetic anomaly. This is a possible burial site, although it is located some distance from the area identified as the waste site location.

The VES data do not show a good correlation with results from drilling activities. The proximity of metal fences and buried underground pipes that interfered with VES readings is probably responsible for the poor agreement of data.

Occurrence of Ground Water

Ground water occurs in the upper zone materials underlying the Waste Burial Area at depths ranging from 19 feet at 10C to 27 feet at 10A. As at the other Flightine sites, ground water exists under unconfined (water table) conditions in the upper zone materials.

Figure 4-5 illustrates the potentiometric surface of the water table as determined in March, 1985. Comparison of the potentiometric surface map for the upper zone ground water and the contour map of the base of the upper zone strongly suggests that the occurrence and direction of movement of ground water in the upper zone is directly related to the configuration of the bedrock surface. Ground water flows to the east under a hydraulic gradient of approximately 0.003.

Soil Chemistry and Water Quality

Split-spoon samples collected in the monitor well installation work were retained and visually examined for any evidence of contamination. Based on the depth and location of the samples, as well as the presence of water, samples of soil were selected for analysis of oil and grease and volatile organic compounds (Methods 601 and 602). The samples were selected for analysis such that the vertical and horizontal distribution of contamination could be evaluated. Results of the analyses are provided on Table 4-11.

After installation, each of the monitor wells was sampled for chemical analysis. A second round of sampling was conducted one month after the first sample set was collected. Results of the two sampling rounds are provided in Table 4-12. Samples were analyzed for organic compounds and purgeable and aromatic organic compounds. Complete reports of all analyses are provided in Appendix A. These data are discussed in the paragraphs below.

TABLE 4-11. RESULTS OF SOIL SAMPLE ANALYSES, WASTE BURIAL AREA (SITE 10), CARSWELL AFB, TEXAS

Parameter[1]	LOCATION				
	10A (28-30 ft)	10B (14-15 ft)	10B (28-30 ft)	10C (24-25 ft)	10C (28-30 ft)
Oil & Grease (ug/g)	<10	<10	<10	<10	<10
1,1,1-Trichloroethane (ug/g)	ND	ND	0.044	ND	ND
Trichloroethylene (ug/g)	0.014	ND	0.067	0.0151	0.021

[1] Parameters shown were detected (ND = not detected).

TABLE 4-12. RESULTS OF GROUND-WATER SAMPLE ANALYSES, WASTE BURIAL AREA (SITE 10), CARSWELL AFB, TEXAS

Parameter	MONITOR WELL[1] 10A Feb	10A Mar	10B Feb	10B Mar	10C Feb	10C Mar
ORGANIC INDICATORS (mg/l)						
Oil & Grease	270	<1	270	<1	310	<1
TOC	1	<1	2	7	5	7
TOX	0.05	1.4 (1.4, 1.4)	0.08	0.02	0.16	0.03
PURGEABLE HALOCARBONS[2] (ug/l)						
Vinyl Chloride	ND, ND	ND, ND	(8.8, ND)	ND, ND	ND, ND	ND, ND
Trichlorofluoromethane	ND, ND	ND, ND	(5.3, ND)	ND, ND	ND, ND	ND, ND
1,1-Dichloroethene	ND, ND	ND, ND	(6.8, ND)	ND, ND	ND, ND	ND, ND
Trichloroethylene	4070 (4120, 4020)	3570 (3550, 3590)	4470 (4510, 4430)	4780 (5000, 4560)	2765 (3660, 1870)	2190 (2130,2250)
Tetrachloroethylene	ND, ND	ND, ND	69.2 (36.4, 102)	43.0 (43.3, 42.7)	ND, ND	ND, ND
PURGEABLE AROMATICS[2] (ug/L)	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND

[1] Duplicate field sample results are reported. The average of the two analytical values is shown first, followed by the actual values used in parenthesis "( )".
[2] Parameters shown were detected; other parameters not listed were scanned but not detected.

Organic Indicators Values of oil and grease, phenols, TOC, and TOX are generally within expected limits for natural soils. In ground water collected at all monitor wells, it was observed that oil and grease values for February were noticably higher than the March values. However, there appeared to be no similar phenomena in other parameters for the same time period. The differences in oil and grease concentrations appear to reflect sample variability. Results of soil analyses for organic indicator parameters indicate background levels.

Purgeable Halocarbons Purgeable halocarbons were detected in all samples collected at Site 10. Levels of purgeable halocarbons, dominantly TCE, in ground water ranged from 1,870 ug/L at 10C to 5,000 ug/L at 10B. In a pattern similar to the one observed at Landfill 5, TCE levels were quite high at the upgradient well (10A), ranging from, 3,550 ug/L to 4,120 ug/L. At well 10B, levels of tetrachloroethylene in the range of 30 to 40 ug/L were also detected. Several other purgeable halocarbon compounds were detected in small quantities at well 10B. The occurrence of low levels of purgeable halocarbons at well 10B in February is likely due to sample variability.

Soils data show that TCE occurs in the saturated zone at all monitor wells at Site 10. In addition, 1,1,1-trichloroethane was detected at a concentration of 0.044 ug/g at boring 10B, along with the highest level of TCE in soil (0.067 ug/g).

Purgeable Aromatics Purgeable aromatic compounds were not detected in soil or water at Site 10.

Significance of Findings

Analyses of soil and ground water samples collected at the Waste Burial Area reveal that halogenated organic compounds are present both upgradient and downgradient of the site. Figure 4-14 illustrates the distribution of TCE, the most significant contaminant observed at Site 10, in upper

zone monitor wells. Samples of soil below the water table were collected during drilling operations at all monitor wells. Levels of TCE were detected at all three wells in the saturated interval, ranging from 0.014 ug/g at well 10A to 0.067 ug/g at well 10B (at 29-30 feet). A sample from the unsaturated zone was analyzed at well 10B, but TCE was not discovered. In addition, 0.044 ug/g of 1,1,1-trichloroethane was detected at a depth of 29-30 feet at well 10B.

Ground-water analyses indicate that there are elevated levels of TCE in the upper zone at all monitor wells. The range of concentrations was 1,870 ug/L to 5,000 ug/L; generally the lowest concentrations were observed at the closest downgradient well, 10B. Well 10B also showed small levels of vinyl chloride, trichlorofluoromethane, and 1,1-dichloroethane. Somewhat higher levels of tetrachloroethylene were observed in well 10B, but not any other wells.

Contaminants in the upper zone ground water would be expected to migrate downgradient to the east in the direction of ground water flow. Ground water moving toward Farmers Branch and the Trinity River can be discharged to the surface in streams or seeps, wells, or can possibly migrate to deeper strata if there are discontinuities in the Goodland/Walnut aquitard. The available data suggest, but do not confirm, that ground water at Landfill 5 will move to the east and be eventually discharged at Farmers Branch or the Trinity River.

4.2.1.4 Fire Training Area 1 (Site 11)

Work performed at Site 11 consisted of geophysical (EMP, VES) surveys, soil sampling using a hand auger, and the installation of upper zone monitor wells. The results of the hydrogeologic, geophysical, and chemical data are discussed in the following paragraphs. Figure 4-11 illustrates the locations and limits of the geophysical surveys and monitor wells.

Topography

Site 11 is located in the southern part of Carswell AFB just west of Coody Drive and north of Landfill 5. The land surface elevation is approximately 605 feet msl. The site now consists of a level and gravel-surfaced area on a drainage divide between an unnamed tributary of Farmers Branch and Farmers Branch.

Geologic Features

Geologic data developed for Site 11 resulted from three activities: geophysical surveys (EMP and VES), geologic sampling during drilling operations, and observations of water levels during and after monitor well installation.

The geologic picture at Site 11 is based on an evaluation of drilling logs developed during the installation of two upper zone monitor wells. Upper zone materials consist of surficial deposits of clayey silt with variable amounts of fine sand and gravel, in turn underlain by sand and gravel deposits. The thickness of the upper zone is approximately 14 feet at both of the monitor wells. Generally, the surficial clay and silt deposits are 5 feet in thickness and the sand and gravel deposits are 8 to 10 feet thick. Shale and limestone of the Goodland Formation underlie the upper zone materials at all locations. Figure 4-3 illustrates the relationship between the upper zone materials and the underlying limestone and shale.

Geophysical Survey

The geophysical surveys conducted at Site 11 were performed as extensions of the work at Landfill 5, just south of the site. EMP data (Figure 4-12) at Site 11 indicate that the range of ground conductivities is on the order of 20 to 40 millimhos/m, consistent with "background" conductivities.

The VES data (VES Station 3 for Landfill 5) reveal a slight increase in resistivity for wider electrode spacing. A high resistivity material is interpreted to occur at a depth of 65 to 90 feet; this material may represent the Paluxy Formation, although there are currently no nearby deep borings to corroborate these geophysical interpretations.

Occurrence of Ground Water

Ground water occurs in the upper zone materials underlying Site 11 at depths ranging from 6 feet at 11B to 9 feet at 11A. The ground water exists under unconfined (water table) conditions in the upper zone materials. Figure 4-5 illustrates the potentiometric surface of the water table as determined in March 1985. As at the other Flightline sites, the occurrence and direction of movement of ground water in the upper zone appears to be directly related to the configuration of the bedrock surface.

Soil Chemistry and Water Quality

Split-spoon samples collected during monitor well installation work were retained and visually examined for any evidence of contamination. Hand auger samples were collected at one location at the center of the site. Based on the depth and location of the samples, as well as the presence of water, samples of soil were selected for analysis consisting of metals, oil and grease, and volatile organic compounds (Methods 601 and 602). The samples were selected for analysis such that the vertical and horizontal distribution of contamination could be evaluated. Results of the analyses are provided on Table 4-13.

After installation, each of the monitor wells was sampled for chemical analysis. A second round of sampling was conducted one month after the first sample set was collected. Results of the two sampling rounds are provided in Table 4-14. Samples were analyzed for metals, organic compounds, and

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TABLE 4-13. RESULTS OF SOIL SAMPLE ANALYSES, FIRE DEPARTMENT TRAINING AREA NO. 1 (SITE 11), CARSWELL AFB, TEXAS

Parameter	LOCATION[1] 11A (9-10 ft)	11B (9-10 ft)	11 C (0 ft)	11 C (2 ft)	11 C (4 ft)	11 C (6 ft)
METALS (ug/g)						
Arsenic	14	<3	<3	<3 (<3,<3)	<3	<3
Barium	<0.23	<0.23	42	39.5 (47,32)	32	20
Cadimium	<0.23	<0.2	<0.39	<0.40 (<0.39,<0.4)	<0.4	<0.39
Chromium	3.0	2.0	6.4	7.6 (7.9,7.3)	6.5	7.1
Lead	<4	<4	8	12.5 (13,12)	13	<4
Mercury	0.14	0.21	0.11	0.14 (0.08,0.19)	0.11	0.15
Selenium	9	<4	11	16.5 (17,16)	20	9
Silver	3.1	<0.18	<0.2	(<0.2,0.72)	1.6	0.74
ORGANIC INDICATORS (ug/g)						
Oil and Grease	<10	<10	100	(2200,<10)	<10	<10
Phenols	<0.1	<0.1	<0.1	<0.1 (<0.1,<10)	<0.1	<0.1
INSECTICIDES[2] (ug/g)	ND	ND	ND	ND,ND	ND	ND
HERBICIDES[2] (ug/g)	ND	ND	ND	ND,ND	ND	ND
PURGEABLE HALOCARBONS[2] (ug/g)						
Trichloroethylene	0.251	ND	0.249	ND,ND	ND	0.257
PURGEABLE AROMATICS[2] (ug/g)	ND	ND	ND	ND,ND	ND	ND

[1]Duplicate field sample results are reported. The average of the two analytical values is shown first, followed by the actual values in parenthesis "( )".
[2]Parameters shown were detected (ND = not detected).

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TABLE 4-14. RESULTS OF GROUND-WATER SAMPLE ANALYSES, FIRE TRAINING AREA 1 (SITE 11), CARSWELL AFB, TEXAS

Parameter	MONITOR WELL[1] 11A Feb	11A Mar	11B Feb	11B Mar
METALS (mg/l)				
Arsenic - ICP	<0.06	<0.06	<0.06	<0.06
Barium	0.16	0.16	0.16	0.16
Cadmium	<0.002	<0.002	<0.002	<0.002
Chromium	<0.005	<0.005	<0.005	<0.005
Lead - ICP	<0.06	<0.06	<0.06	<0.06
Mercury	0.0002	0.0009	0.0005	0.0002
Selenium - ICP	<0.06	<0.06	<0.06	<0.06
Silver	<0.002	<0.002	<0.002	<0.002
METALS (mg/L) - AA (resampled November 1985)				
Arsenic		0.004		0.041
Lead		<0.002		<0.002
Selenium		<0.003		<0.003
ORGANIC INDICATORS (mg/l)				
Oil & Grease	50 [55, 45]	<1	200	<1
Phenols	0.006	<0.005	0.005	<0.005
TOC	7	7	15	14
TOX	0.075 [0.01, 0.14]	0.08	0.04	0.25 [0.27, 0.23]
HERBICIDES[2] (ug/l)				
2,4,5-T	[ND, 0.2]	ND	ND	ND
PESTICIDES[2] (ug/L)	ND, ND	ND	ND	ND
PURGEABLE HALOCARBONS[2] (ug/l)				
Trichlorofluoromethane	2.35 [2.3, 2.4]	5.1 [4.4, 5.7]	ND, ND	[ND, 3.2]
Trichloroethylene	ND, ND	ND, ND	[ND, 1.4]	[ND, 1.8]
PURGEABLE AROMATICS[2] (ug/l)				
Benzene	ND, ND	ND, ND	ND, ND	2.6 [1.5, 3.8]

[1] Duplicate field sample results are reported. The average of the two analytical values is shown first, followed by the actual values used in parenthesis "[ ]".

[2] Parameters shown were detected (ND = not detected).

purgeable and aromatic organic compounds. Complete reports of all analyses are provided in Appendix A. These data are discussed in the paragraphs below.

Heavy Metals Concentrations of heavy metals in ground water were determined to be less than the federal standards for drinking water (Table 4-1). There appear to be no trends in the concentrations of metals relative to upgradient or downgradient positions of the monitor wells. Likewise, results of soil analyses indicate that the metals contents of the soil are generally within expected limits for natural soils.

Organic Indicators Values of oil and grease, phenols, TOC, and TOX are generally within expected limits for water and soil. In surface water and ground water, it was observed that oil and grease values for February were noticably higher than the March values. However, there appeared to be no similar phenomena in other parameters for the same time period. The differences in oil and grease concentrations appear to reflect sample variability. Results of soil analyses showed expected values for all organic indicator parameters.

Insecticides and Herbicides A small amount (0.2 ug/L) of the herbicide 2,4,5-TP was detected in one of two field samples from the February sampling event at well 11A. There are currently no water-quality standards for this herbicide.

Purgeable Halocarbons Purgeable halocarbons (TCE and trichlorofluoromethane) were detected at low levels in ground water at Site 11. TCE ranged from not detected to 1.8 ug/L. The levels observed in the upper zone ground water are close to the analytical detection limits for the compounds, suggesting that organic contaminants in ground water are quite low relative to the findings at adjacent sites. TCE was also detected in soils, both at the center of the site and north of the site.

Purgeable Aromatics Ground-water analyses revealed low levels of benzene, ranging from not detected to 3.6 ug/L at well 11B in March.

Significance of Findings

Results of soil and ground-water sampling conducted at Site 11 indicate that the upper zone contains some low levels of halogenated organic compounds. Figure 4-14 illustrates the areal distribution of TCE, the principal contaminant observed in the upper zone at the flightline area sites. Results of metals analyses and other organic parameters showed essentially background levels.

4.2.1.5 Fire Training Area 2 (Site 12)

Work performed at Fire Training Area 2 consisted of geophysical (EMP, VES) surveys, soil sampling using a hand auger, installation of upper zone monitor wells, and collection of surface water samples. The results of the hydrogeologic, geophysical, and chemical data are discussed in the following paragraphs. Figure 4-6 illustrates the locations and limits of the geophysical surveys, monitor wells, and surface water sampling points.

Topography

Site 12 is located in the southern part of Carswell AFB just west of the radar facility. The site is an oval-shaped gravel surface containing rectangular metal containers. A low berm surrounds the basically flat area. Surface drainage is generally to the north to an unnamed tributary of Farmers Branch.

Geologic Features

Geologic data developed for Site 12 resulted from three primary activities: geophysical surveys (EMP and VES), geologic sampling during drilling operations, and observations of water levels during and after monitor well installation.

The geologic picture at Site 12 is based on an evaluation of drilling logs developed during the installation of three upper zone monitor wells. Upper zone materials consist of surficial deposits of clayey silt with variable amounts of fine sand and gravel, in turn underlain by sand and gravel deposits. The thickness of the upper zone ranges from 17 to 37 feet. Surficial clay and silt deposits are 10 feet in thickness and the sand and gravel deposits are 7 to 27 feet thick. It was observed that in most borings in the vicinity of the flightline that the grain size of the sand and gravel increases with depth.

Shale and limestone of the Goodland Formation underlie the upper zone materials at all locations. The top of the Goodland occurs at a maximum depth of 39 feet in the northeast corner of the site (at 12B) and at its shallowest depth of 17 feet in the southwest (at 12A). Limestone of the Goodland Formation crops out just southeast of the site in a stream that flows to Farmers Branch. The bedrock/upper zone contact slopes steeply to the northeast under the site. Figure 4-3 illustrates the relationship between the upper zone materials and the underlying limestone and shale.

Drilling at P1 just north of the site revealed that the Goodland and Walnut Formations are 30 feet thick. The Paluxy Formation underlies the Goodland and Walnut Formations and is composed of fine sand containing lignite and pyrite and interbedded with occasional lenses and layers of shale.

Geophysical Survey

At this site, the EMP data were distorted by several features. The areas affected are: the northwest corner which contains a buried sewer pipe running approximately NE-SW, the line along station 450 where an underground telephone cable is located, the area between the fuel storage tank and the training pit containing several buried sprinkler pipes, and the line at approximately station 80 where there is a buried pipe or cable. The EM31 (horizontal) data shown in Figure 4-15 reveals an area of anomalously high

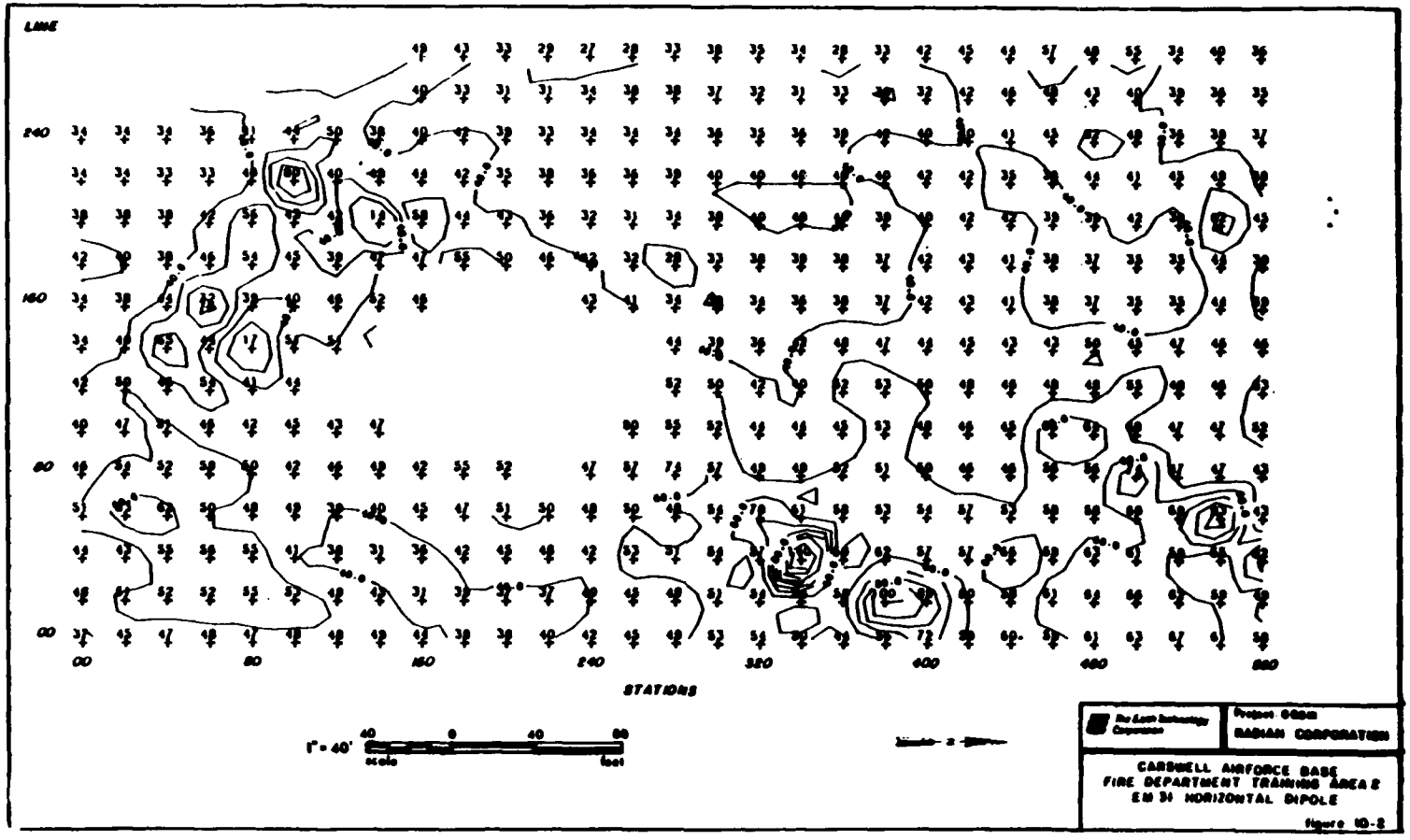

Figure 4-15. Electromagnetic Profile Date (EM31), Fire Department Training Area No. 2 (Site 12), Carswell AFB, Texas.

conductivity northeast of the burn pit. The other EMP data also show this anomaly, which corresponds to a small drainage coming from the pit. Outside the anomalous areas, the conductivities vary only slightly across the survey area. The EM-34 shows a trend of higher conductivities southward on the grid. Variations such as this are probably due to natural changes in soil character.

Most VES data appear to be affected by near-surface inhomogenities, and probably do not represent natural conditions.

Occurrence of Ground Water

Ground water occurs in the upper zone materials underlying Site 12 at depths ranging from 13 feet at 12A to 30 feet at 12B and 12C. The ground water exists under unconfined (water table) conditions in the upper zone materials. Figure 4-5 illustrates the potentiometric surface of the water table as determined in March, 1985. Comparison of the potentiometric surface map for the upper zone ground water and the contour map of the base of the upper zone strongly suggests that the occurrence and direction of movement of ground water in the upper zone is directly related to the configuration of the bedrock surface. The direction of ground-water flow is to the northeast.

Soil Chemistry and Water Quality

Split-spoon samples collected during the monitor well installation work were retained and visually examined for any evidence of contamination. Hand auger samples were also collected at the center of the site. Based on the depth and location of samples, as well as the presence of water, samples of soil were selected for analysis of metals, oil and grease, and volatile organic compounds (Methods 601 and 602). The samples were selected for analysis such that the vertical and horizontal distribution of contamination could be evaluated. Results of the analyses are provided on Table 4-15.

TABLE 4-15. RESULTS OF SOIL SAMPLE ANALYSES, FIRE TRAINING AREA 2 (SITE 12), CARSWELL AFB, TEXAS

Parameter	LOCATION[1] 12A (10-88 ft)	12B (0-10 ft)	12B (14-16 ft)	12B (24-26 ft)	12C (24-26 ft)	12F (0 ft)	12F (2 ft)	12F (4 ft)	12F (6 ft)	12F (8 ft)
METALS (ug/g)										
Arsenic	<5.7 (<5.8, <5.5)	<5.2 (<5.5, <5.8)	<5.5	<4.8	<5.2	<3	<11 (10, <3)	<3	<3	<3
Barium	28 (25, 30)	24 (20, 28)	2.4	4.4	7.5	20	82 (84, 180)	74	50	23
Cadmium	0.28 (<0.10, 0.47)	0.45 (0.37, 0.53)	<0.10	<0.10	<0.17	<0.20	0.54 (0.80, <0.20)	<0.20	<0.20	<0.20
Chromium	4.8 (4.8, 4.8)	5.0 (4.8, 5.2)	1.4	0.84	2.5	7.0	13 (15, 11)	14	9.2	8.0
Lead	8.0 (9.8, 6.2)	10.0 (8.2, 13)	<7.2	<8.4	<7.0	10	52 (40, 64)	10	13	<4
Mercury	<0.04 (<0.04, <0.04)	<0.04 (<0.04, <0.04)	<0.04	<0.04	<0.04	0.12	0.07 (<0.05, 0.09)	0.10	<0.05	0.21
Selenium	0.5 (<7.0, 0.2)	12.2 (0.2, 15)	<7.2	<0.4	<7.0	<4	25 (26, 32)	24	17	<4
Silver	0.53 (0.50, 0.56)	0.50 (0.50, 0.53)	0.01	<0.10	<0.17	2.0	2.2 (2.7, 1.6)	1.6	1.0	0.46
ORGANIC INDICATORS (ug/g)										
Oil & Grease	<10.0, <10.0	<10.0, <10.0	700	<10	<10	17,000	13,000; 11,000	9,000	9,000	11,000
Phenols	<0.1, <0.1	<0.1, <0.1	<0.1	<0.1	<0.1	<0.1	1.5, 1.0	1.2	2.0	2.4
PURGEABLE HALOCARBONS[2,3] (ug/g)										
1,2-Dichlorobenzene	ND, ND	ND, ND	ND	ND	ND	ND	0.660 (0.660, 0.670)	1.050	1.170	0.721
1,3-Dichlorobenzene	ND, ND	ND, ND	ND	ND	ND	ND	ND, ND	0.464	0.364	0.273
1,1,2,2-Tetrachloroethane	ND, ND	ND, ND	ND	ND	ND	ND	0.273 (0.271, 0.274)	0.327	0.384	1.000
Trichloroethylene	ND, ND	ND, ND	ND	ND	ND	256	0.277 (0.276, 0.278)	0.290	0.330	0.365
Trichlorofluoromethane	ND, ND	ND, ND	ND	ND	ND	210	ND, ND	ND	ND	ND
PURGEABLE AROMATICS[2,3] (ug/g)										
Benzene	ND, ND	ND, ND	ND	ND	ND	0.44	(ND; 752.0)	ND	ND	ND
Ethyl Benzene	ND, ND	ND, ND	2.0	ND	ND	32.2	(ND, 33.700)	26.4	63.0	110.0
Toluene	ND, ND	ND, ND	1.4	ND	ND	12.2	(ND, 27.400)	36.1	64.3	134.0

[1] Duplicate field sample results are reported. The average of the two analytical values is shown first, followed by the actual values used in parenthesis "( )".
[2] Parameters shown were detected (ND = not detected).
[3] Method detection limits: Purgeable halocarbons - 10 ug/Kg for 12A, 12B, 12C, and 12F
Purgeable aromatics - 200 ug/Kg for 12A, 12B, 12C; 2500 ug/Kg for 12F (0), 12F (4), 12F (6), 12F (8); 12,500 ug/Kg and 800 ug/Kg for splits of 12F (2).

After installation, each of the monitor wells was sampled for chemical analysis. A second round of sampling was conducted one month after the first sample set was collected. Results of the two sampling rounds are provided in Table 4-16. Surface water samples were also collected at one location just north of the site (Table 4-17). Samples were analyzed for metals, organic compounds, and purgeable and aromatic organic compounds. Complete reports of all analyses are provided in Appendix A. These data are discussed in the following paragraphs.

Heavy Metals Results of ground water analyses from the three monitor wells indicate concentrations of metals below federal regulatory limits for drinking water (Table 4-1). Similarly, concentrations of metals in soils are generally low, with one exception. The exception to this trend is seen in the results from boring 12F, the site of hand augered samples from the center of the fire training area. Samples from this location reveal elevated concentrations of lead and selenium. Differences in arsenic levels in duplicate samples at 12F (2-foot depth) can be attributed to sample variability. In addition, the arsenic concentration in surface water north of the site was relatively high during the January sampling event, but low in February.

Organic Indicators Concentrations of organic indicator parameters varied widely in samples collected at the fire training area. Levels of organic parameters were generally low in ground water collected from the monitor wells. However, results of soil analyses revealed excessive concentrations of oil and grease in samples collected in the center of the fire training area. These concentrations ranged from 8,200 ug/g to 17,000 ug/g are generally correlate to the high values of purgeable aromatics detected in soil at the same location. Results of the analyses of surface water contrasted sharply from January to February. The January sample, collected within a few days of a fire training exercise, showed extremely high levels of oil and grease and TOC that were consistent with the contaminated appearance of the sample. In contrast, the February sample had very low levels of oil and grease and TOC, suggesting that a training episode had not been conducted recently.

TABLE 4-16. RESULTS OF GROUND-WATER SAMPLE ANALYSES, FIRE TRAINING AREA 2 (SITE 12), CARSWELL AFB, TEXAS

Parameter	MONITOR WELL[1] 12A Feb	12A Mar	12B Feb	12B Mar	12C Feb	12C Mar
METALS (mg/l)						
Arsenic - ICP	<0.06 [<0.06, <0.06]	<0.06	<0.06	<0.06	<0.06	<0.06
Barium	0.079 [0.1, 0.057]	0.11	0.14	0.16	0.18	0.18
Cadmium	<0.0002 [<0.002, <0.002]	<0.002	<0.002	<0.002	<0.002	<0.002
Chromium	<0.0005 [<0.005, <0.005]	<0.005	<0.005	<0.005	<0.005	<0.005
Lead - ICP	<0.06 [<0.06, <0.06]	<0.06	<0.06	<0.06	<0.06	<0.06
Mercury	<0.0002 [<0.0002, <0.0002]	<0.0002	0.0003	<0.0002	<0.0002	<0.0002
Selenium - ICP	<0.06 [<0.06, <0.06]	<0.06	<0.06	<0.06	<0.06	<0.06
Silver	<0.002 [<0.002, <0.002]	<0.002	<0.002	<0.002	<0.002	<0.002
METALS (mg/L) - AA (resampled November 1985)						
Arsenic		<0.003		<0.003		0.004
Lead		<0.002		<0.002		<0.002
Selenium		<0.003		<0.003		<0.003
ORGANIC INDICATORS (mg/l)						
Oil & Grease	37.5 [41, 34]	<1	34	<1	89	<1, <1
Phenols	0.017 [0.013, 0.021]	<0.005	0.017	<0.005	0.005	0.006
TOC	<1 [<1, <1]	<1	1	<1	5	<1
TOX	<0.1 [<0.01, <0.01]	0.01	0.38	0.38	0.03	0.11, 0.10
PURGEABLE HALOCARBONS[2] (ug/L)						
Vinyl Chloride	ND, ND	ND, ND	ND, ND	ND, ND	9.0 [9.4, 8.5]	ND, ND
Trichlorofluoromethane	14.2 [12.6, 15.7]	4.0 [3.8, 4.1]	ND, ND	ND, ND	12.0 [13.3, 10.6]	ND, ND
1,1-Dichloroethene	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	2.5 [2.5, 2.5]
1,1-Dichloroethane	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	5.85 [5.9, 5.8]
1,1,1-Trichloroethane	ND, ND	2.8 [2.8, 2.8]	ND, ND	ND, ND	2.9 [2.9, 2.9]	2.9 [2.9, 2.9]
Trichloroethylene	ND, ND	2.2 [2.2, 2.2]	360 [358, 362]	190 [187, 193]	4.8 [4.8, 4.8]	5.7 [5.8, 5.6]
Tetrachloroethylene	ND, ND	2.55 [2.5, 2.6]	161.5 [159, 164]	89.6 [87, 92.2]	4.85 [4.7, 4.8]	8.4 [8.8, 8.1]
PURGEABLE AROMATICS[2] (ug/l)						
1,2-Dichlorobenzene	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND	[ND, 3.8]
1,4-Dichlorobenzene	ND, ND	ND, ND	ND, ND	[2.3, ND]	ND, ND	3.8 [4.1, 3.0]

[1] Duplicate field sample results are reported. The average of the two analytical values is shown first, followed by the actual values used in parenthesis "[ ]".

[2] Parameters shown were detected; other parameters not listed were scanned but not detected.

TABLE 4-17. RESULTS OF SURFACE-WATER SAMPLE ANALYSES, FIRE TRAINING AREA 2, CARSWELL AFB, TEXAS

Parameter	January	February
METALS (mg/L)		
Arsenic	0.16	<0.06
Barium	0.29	0.15
Cadmium	0.007	<0.002
Chromium	0.017	<0.005
Lead	0.081	<0.08
Mercury	0.0003	0.0006
Selenium	<0.08	<0.08
Silver	<0.002	<0.002
ORGANIC INDICATORS (mg/L)		
Oil & Grease	84,000	1
Phenols	0.14	
TOC	50,000	86
TOX	0.63	<0.01
PURGEABLE HALOCARBONS (ug/L)		
Trichlorofluoromethane	ND	3.5
PURGEABLE AROMATICS (ug/L)	ND	ND

Note: ND = not detected.

Purgeable Halocarbons Concentrations of purgeable halocarbons were present in nearly all ground water samples collected at the fire training area. Wells 12A and 12C revealed levels of purgeable halocarbons generally less than 10 ug/L. However, well 12B, constructed directly downgradient of the site and adjacent to a drainage leading from the site, showed the highest levels of purgeable halocarbons, well over 50 ug/L. The two compounds detected in this well were TCE and tetrachloroethylene, with concentrations in the February samples exceeding those in March. The surface-water samples were virtually free of purgeable halocarbons.

Only soil collected from the center of the site exhibited levels of purgeable halocarbons. TCE was detected in levels ranging from 0.256 to 0.395 ug/g, generally increasing in concentration with depth at boring 12F. In addition, dichlorobenzenes were also detected at 12F, ranging from not detected to 1.7 ug/g.

Purgeable Aromatics Ground-water analyses conducted at Site 12 revealed only very low levels of purgeable aromatics, consisting of dichloroenzenes. However, results of soil analyses show substantial levels of purgeable aromatics directly under and downgradient from the site in the unsaturated zone. The analyses detected three compounds: benzene, ethyl benzene, and toluene. Samples from boring 12F were highly contaminated, with oil and grease concentrations ranging from 8,200 to 13,000 ug/g. Resulting analytical interferences necessitated varying dilutions of samples. Increased dilution increases the detection limit. This accounts for the apparent disagreement between the two duplicate sample results (see footnotes, Table 4-15).

Significance of Findings

Results of soil and ground-water analyses at Site 12 indicate that many of the samples have high levels of volatile organic compounds, both

halogenated and aromatic. The following paragraphs consider the soil data obtained within the fire training area itself and the upgradient and downgradient monitor wells, the results of water-quality analyses from the upper zone monitor wells, and a surface-water sampling point downslope of the fire training area.

A series of hand-auger samples from the center of the fire training area reveal that the soil has high levels of both halogenated and aromatic organic compounds. Soil concentrations of ethyl benzene and toluene are all greater than 10 ug/g, with greater than 100 ug/g benzene and toluene observed in the 8-foot sample. Results of the oil and grease analyses also show a similar trend. The results from 2 feet below the land surface suggest an apparent conflict between the duplicate samples; however, the extreme levels of benzene and benzene derivatives apparently produced a GC scan in which it was difficult to distinguish between various hydrocarbon peaks.

Levels of organic contamination are much greater at the center of the site than away from the site. Analysis of soil samples collected at points hydraulically upgradient and downgradient of the site revealed virtually no contamination. However, ethyl benzene and toluene were detected in soil directly north of the site at a depth of 14 to 15 feet below the land surface. Moreover, a distinct hydrocarbon odor and corresponding reaction from the air monitoring device was noted at the 14-15 foot depth at well 12B. No contamination was observed in samples at deeper or shallower levels; these data are also supported by the qualitative observations made during the drilling operations.

Results of ground-water quality analyses at the three ground water monitor wells indicate that volatile organic compounds occur in the upper zone ground water. Upgradient of the site, at well 12A, the very minor amounts of halogenated organic compounds detected do not suggest a contamination problem. Similarly, results of analyses from well 12C indicate that a wide variety of organic compounds are present in the water in low concentrations. The

position of well 12C, tangent to the inferred direction of ground water flow in the upper zone under Site 12, suggests that any main zone of contamination would not be detected at this location. However, the location of well 12B is both directly downgradient of the site and coincides with the position of a drainage ditch that carries overflow from the fire training area. This drainage was observed to be contaminated with JP-4 during most of the field activities, particularly during January. Ground-water analyses from well 12B indicate that significant levels of trichloroethylene (not detected to 362 ug/L) and tetrachloroethylene (not detected to 164 ug/L) are present in the upper zone ground water. This well is likely to detect the main body of contamination owing to its location near the drainageway and directly downgradient from the fire training site.

Analyses of surface-water samples collected downstream of the fire training area indicate that the chemistry of the water is highly variable. Water collected in January 1985, within a few days after a fire training exercise, revealed high levels of organic indicator compounds such as oil and grease and total organic carbon. Water collected one month later and within a few days of a rainy period revealed relatively low concentrations of the same indicator parameters. In both cases, volatile organic compounds were not detected at all or were in very low concentrations. Two conclusions can be made: first, the surface water quality is highly variable and corresponds directly to the performance of fire training exercises, and second, volatile compounds are lost to the atmosphere within a few days and within a short distance from the training area.

4.2.2 East Area Investigation

The investigation of the East area included the analysis of soil obtained from 9 hand-augered holes, 3 surface-sediment samples, 11 soil borings, and soil collected during the drilling of 7 ground-water monitor wells. Water samples were collected from two surface water sites, and from the soil borings and monitor wells. Geophysical surveys were also performed at selected sites in the East area. The results and significance of the hydrogeologic data are discussed in the following paragraphs.

Topography

The East area is located on land that gently slopes eastward to the West Fork of the Trinity River and southward to Farmers Branch. Elevations range from 595 feet msl west of the POL Tank Farm to 560 feet msl on the flood plain above the Trinity River. No abrupt elevation changes occur within this area except close to the Trinity and Farmers Branch.

Geologic Features

The results of monitor well installation and soil boring drilling show that the geologic settings of the Flightline area and the East area are similar. Locations of monitor wells and soil borings in the East area are shown in Figure 4-16. The major elements of the shallow geologic setting are illustrated in a series of cross-sections (Figures 4-17 through 4-20). The geology of the East area consists of a thin veneer of alluvial material (upper zone) overlying the Goodland Limestone. The alluvium consists of clay, sand, and gravel. The Goodland Limestone contains limestone, weathered limestone, and shale. No wells were drilled in the East area that penetrated through the Goodland/Walnut Formations into the Paluxy Formation.

The upper zone in the East area generally consists of 5 to 15 feet of gray to black clay overlying 2 to 10 feet of fine-grained sand and up to 5

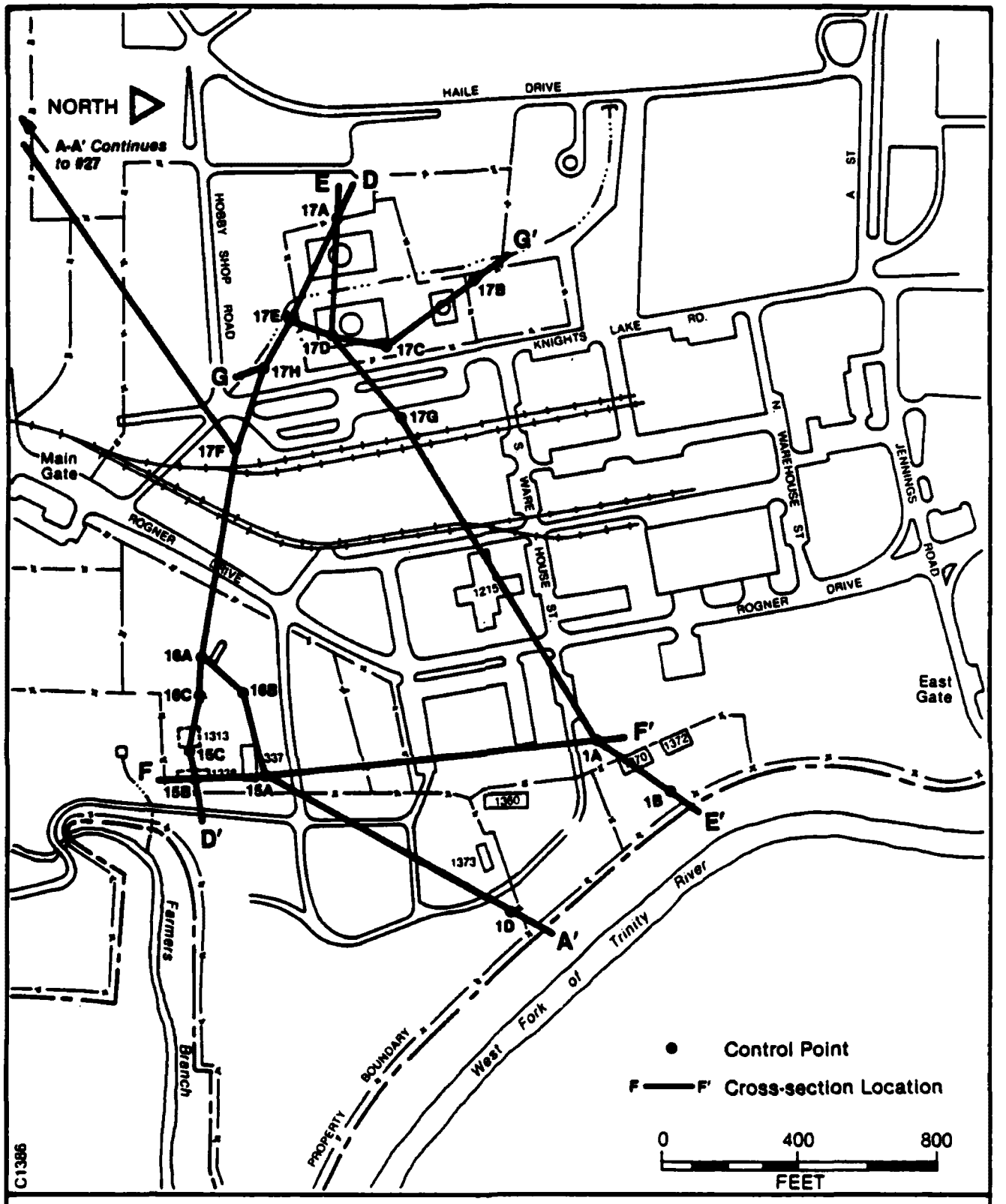

Figure 4-16. Detail of Monitoring Locations, East Area, Carswell AFB, Texas.

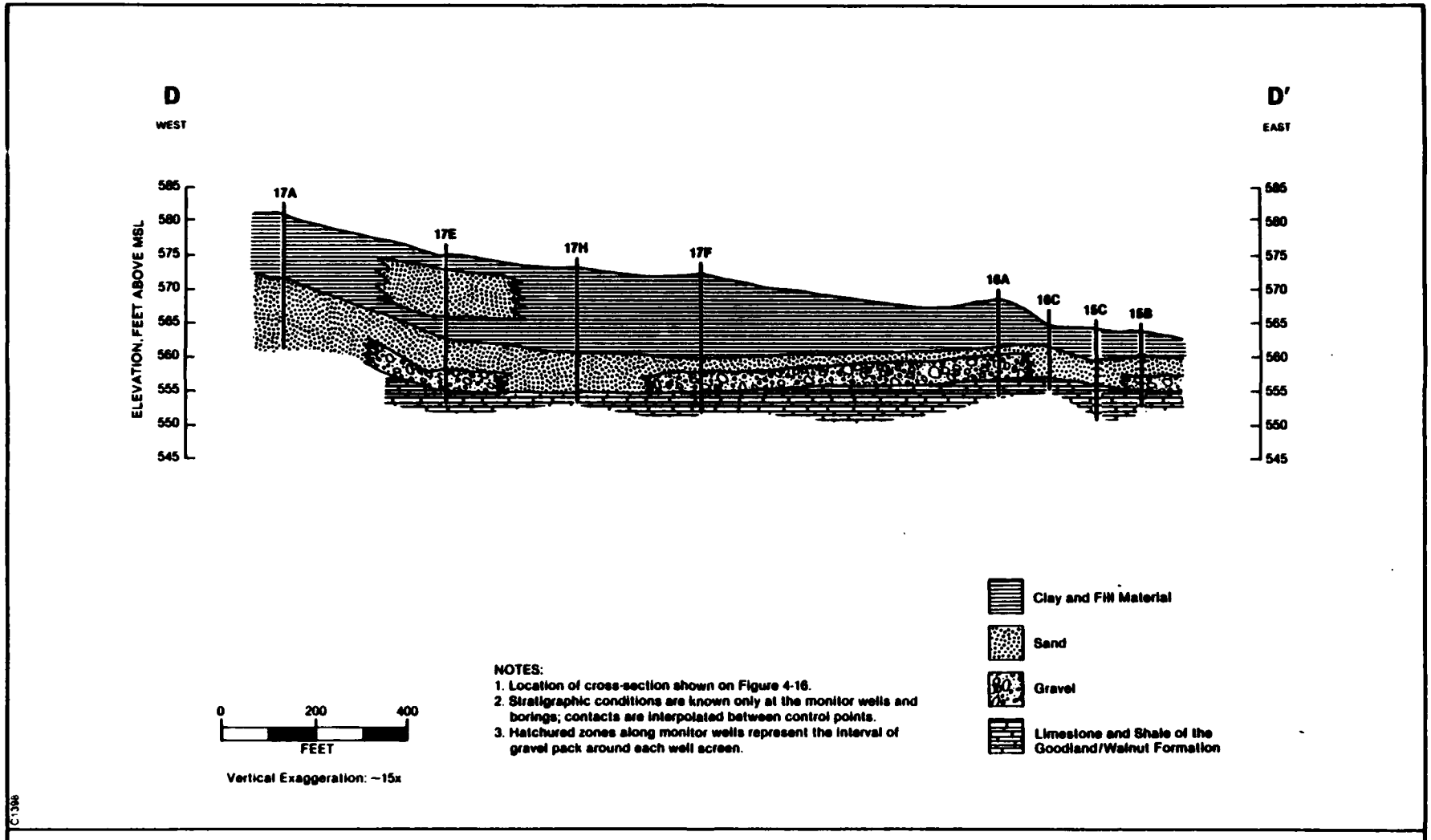

Figure 4-17. Geologic Cross-Section D-D', Carswell AFB, Texas.

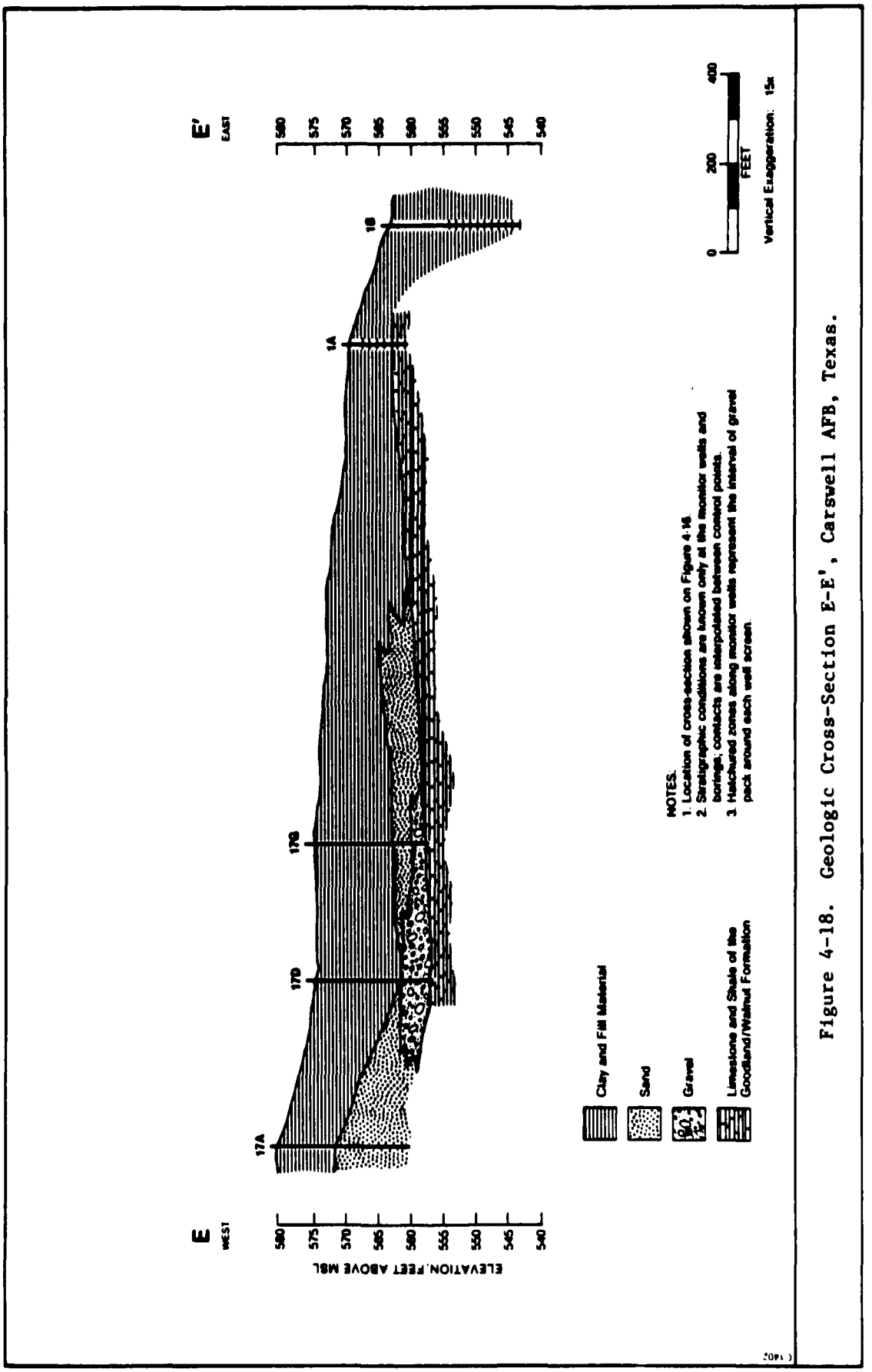

Figure 4-18. Geologic Cross-Section E-E', Carswell AFB, Texas.

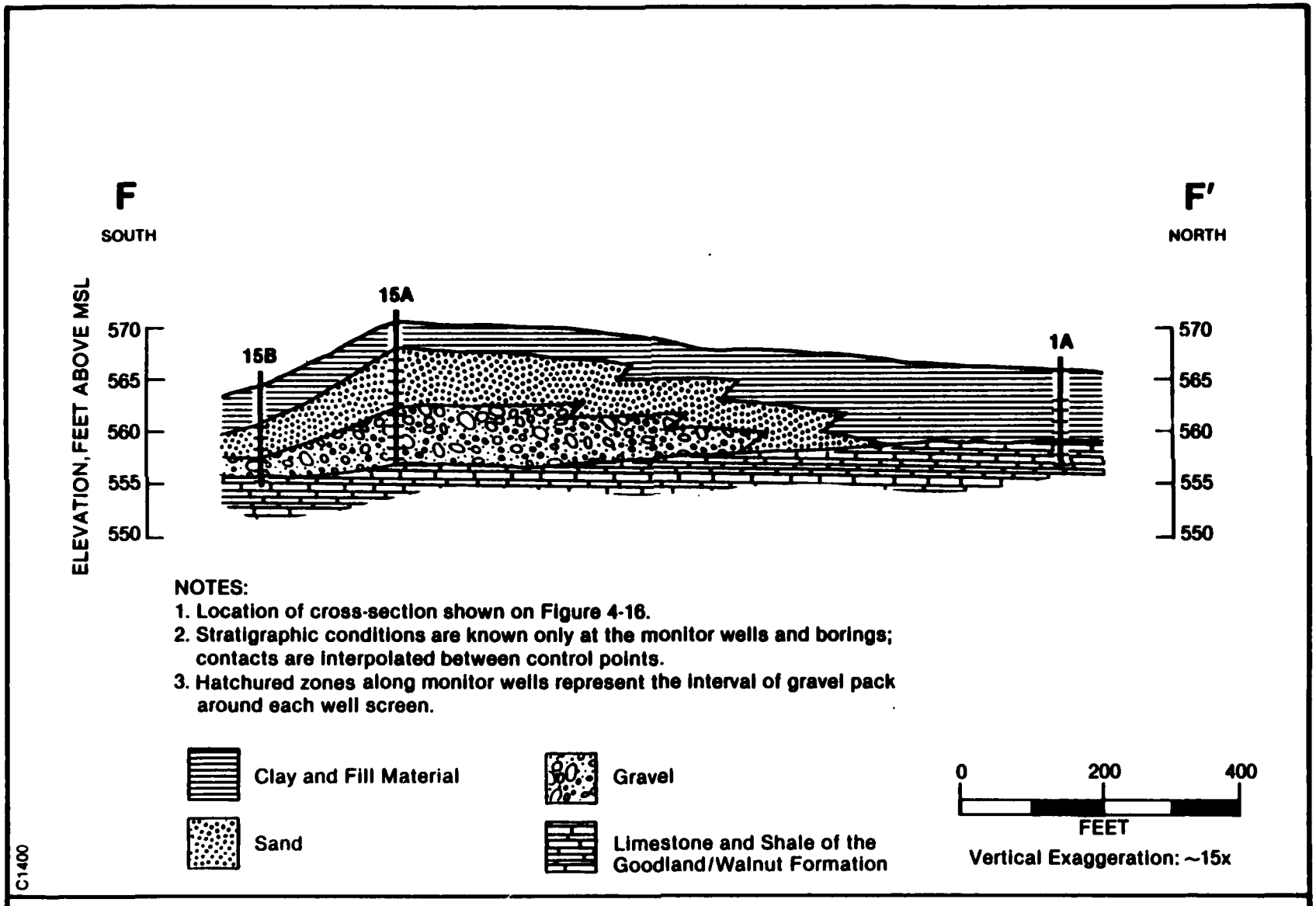

Figure 4-19. Geologic Cross-Section F-F', Carswell AFB, Texas.

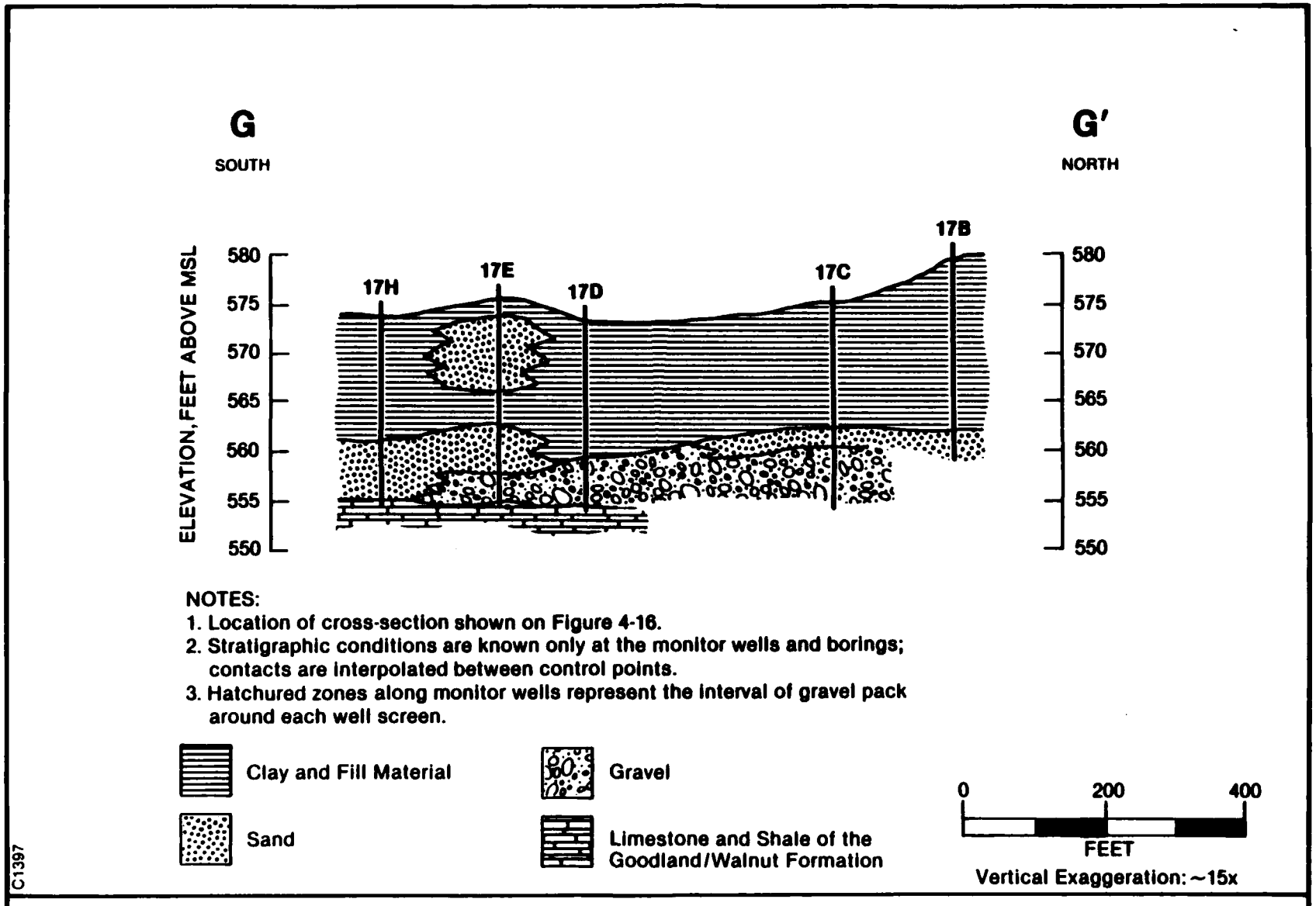

Figure 4-20. Geologic Cross-Section G-G', Carswell AFB, Texas.

feet of gravel. The clay is often sandy and occasionally contains pebbles, freshwater gastropod shells, and gravel stringers. Limonite stains occur in some clay beds. Two types of sand occur in the alluvium and are distinguished on the basis of their color. One sand is tan to pink and the other is light gray. Both sands are predominantly fine-grained, though medium-grained sand is a common subsidiary constituent. The gravel ranges from 1/8 inch to over 1 inch in diameter. Sand is a common accessory in gravel layers, and clay is sometimes present.

The continuity of the permeable sand and gravel beds across the East area is shown on the geologic cross-sections (Figure 4-17 through Figure 4-20). The east-west dip oriented section D-D' shows that an approximately 5 feet thick sand/gravel layer probably reaches from the POL Tank Farm to close to Farmers Branch. The other dip oriented section, E-E', shows the sand/gravel layer pinching out before it reaches the West Fork of the Trinity River. The strike oriented section, F-F', shows the lateral pinching out of the sand and gravel layers toward the DPDO. The other strike oriented section, G-G', shows a continuous sand/gravel layer beneath the POL Tank Farm.

The Goodland Formation in the East area is usually encountered between 7 and 20 feet, though it is deeper in some wells. In general, the depth to the Goodland decreases as the Trinity River is approached. The exception to this trend is found immediately adjacent to the Trinity, where the depths to the Goodland exceed 20 feet. The Goodland in the East area occurs as gray, hard limestor nd as blue-gray, mottled shale. The elevations at which the limestone ountered in the East area wells and borings are listed on Table 4 ur map of the elevation of the base of the upper zone is shown in . Most of the East area occurs on a fairly level limestone s ver, the Goodland dips steeply eastward within 400 feet of the Tri n the southern part of the East area, the limestone surface also rd, at a more gentle slope, toward Farmers Branch. The south and ea lopes are probably due to erosion of the Goodland by the respective s

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TABLE 4-18. ELEVATION OF THE TOP OF THE GOODLAND LIMESTONE, EAST BASE AREA, CARSWELL AFB, TEXAS

Well or Boring	Elevation, feet msl
1A	560
1B	<540
1C	528
1D	538
15A	557
15B	555
15C	556
16A	556
16B	557
16C	557
17A	<560
17B	<558
17C	<554
17D	555
17E	555
17F	555
17G	556
17H	555

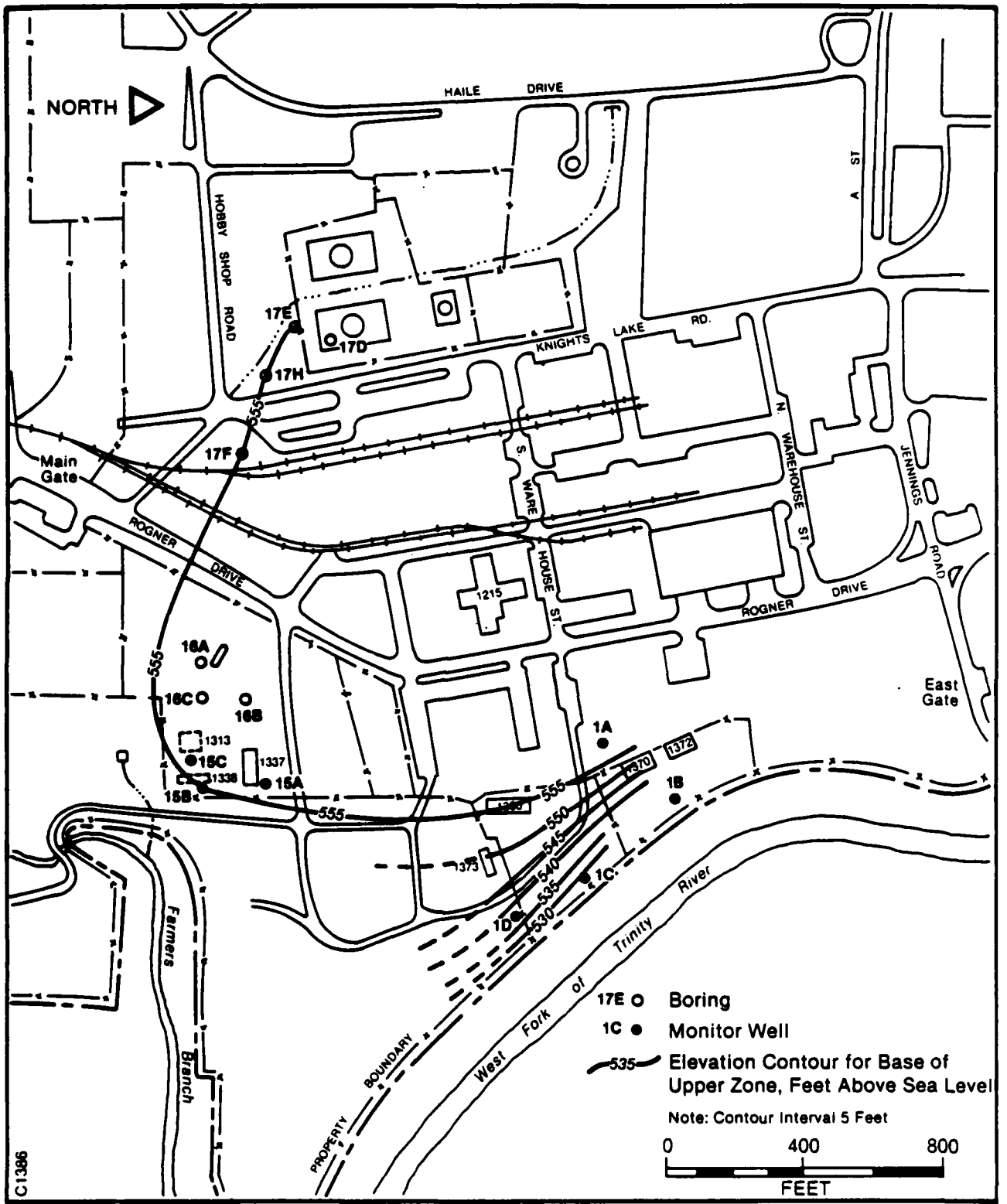

Figure 4-21. Contour Map of the Base of the Upper Zone, East Area, Carswell AFB, Texas.

Geophysical Surveys

Geophysical surveys were conducted at Sites 1 and 16 in the East area. Electromagnetic profiling (EMP) and earth resistivity (vertical electrical soundings, VES) were performed at Landfill 1. The purpose of the EMP and VES surveys was to provide indirect information on the character of subsurface materials, including significant variations in thickness of geologic units, occurrence of buried objects, the position of the water table, and occurrence of soil and ground-water contamination. The magnetometer survey at Site 16 was conducted to locate buried gasoline storage tanks.

The EMP surveys at Landfill 1 located two high conductivity areas leading eastward from the landfill. The VES surveys were interpreted as showing bedrock to be at a depth of approximately 4 to 5 feet on the west side of the DPDO. The magnetometer survey detected two possible locations for the buried tanks at Site 16. One area is northeast of the abandoned concrete island at the site, the other location is southwest of the island.

Occurrence of Ground Water

Ground water was observed in the upper zone of the East Base area during soil boring drilling and monitor well installation. Water levels in the soil borings were either measured with a steel tape or estimated during drilling by noting the state of saturation of soil samples. Water levels in monitor wells were recorded during water sampling activities in February and March, 1985. The depth to ground water in the East area ranges from 7 to 23 feet below ground surface. The depth to water (estimated for soil borings) and the elevation of water at each well and boring is recorded on Table 4-19.

A water-level elevation map for the upper zone of the East area is presented in Figure 4-22. The five-foot contour lines reveal decreasing hydraulic heads from west to east, indicating ground-water flow toward the Trinity River. However, the one-foot contour interval shows that ground-water

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TABLE 4-19. WATER LEVEL DATA IN THE EAST AREA, CARSWELL AFB, TEXAS

Well	February 1985 Depth to Water (ft)	February 1985 Elevation of Water (ft,msl)	March 1985 Depth to Water (ft)	March 1985 Elevation of Water (ft,msl)
1A	7.93	562.49	7.71	562.71
1B	16.46	544.23	18.17	542.07
1C	18.95	541.51	18.60	541.43
1D	22.88	541.18	22.52	541.54
15A	10.05	560.19	10.00	560.24
15B	8.96	559.13	8.94	559.15
15C	8.76	559.11	8.77	559.10

Borehole	February 1985 Depth Water Encountered (ft)	February 1985 Elevation of Water Encountered (ft,msl)
16A	approx. 10	558
16B	" 10	560
16C	" 7	558
17A	" 9.5	571
17B	" 16	563
17C	" 12	562
17D	" 13	560
17E	" 12.5	563
17F	" 12.5	560
17G	" 12	561
17H	" 13	561

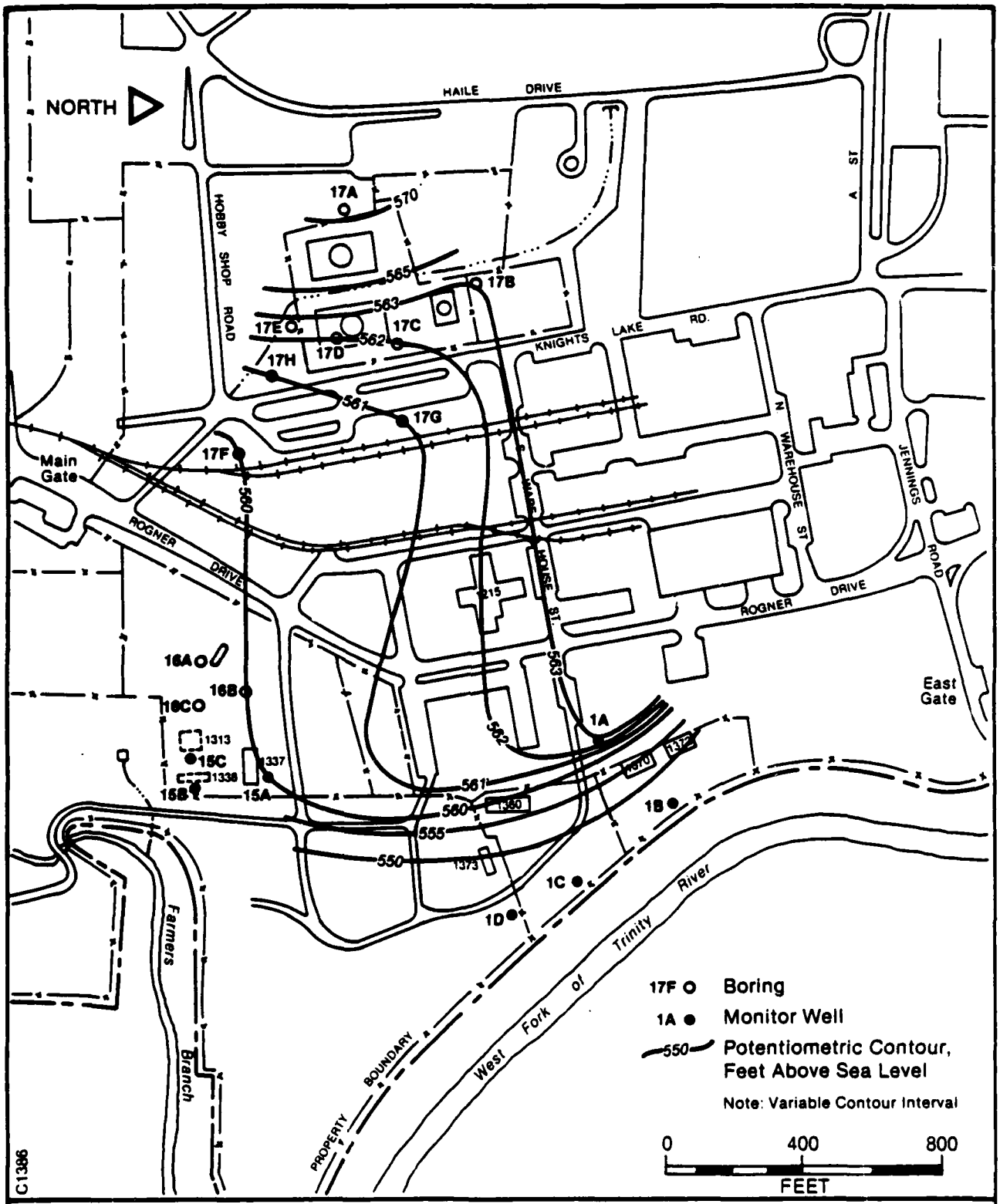

Figure 4-22. Potentiometric Surface Map of the Upper Zone, East Area, Carswell AFB, Texas.

flow across a large part of the East area is from north to south, toward Farmers Branch. The direction of ground-water flow in the upper zone is apparently controlled by the elevation of the upper surface of the Goodland Limestone. This observation is consistent with the finding at the flightline area, where ground water in the upper zone also occurs on top of the Goodland Limestone.

No information on the nature of the Paluxy Aquifer in the East area is available because drilling activities in this area were confined to the upper zone.

Soil Chemistry and Water Quality

Results of ground-water, surface-water, and soil sampling performed in the East area are provided and discussed on a site-by-site basis.

4.2.2.1 Site 1, Landfill 1

Site 1 is located at the DRMO yard. The locations of the upper zone monitor wells installed at Site 1 are shown on Figure 4-23. The upgradient well, 1A, is located in the southeast corner of the park bordering the DRMO to the west. Well 1A is the most shallow of the Site 1 wells, with the Goodland Limestone only 7 feet below the surface. Wells 1B and 1C are located inside of the DRMO yard. Well 1B, in the north yard, was completed at 20 feet without encountering limestone. Well 1C, located in the south yard, was completed upon reaching a shale member of the Goodland Limestone at a depth of 33 feet. Well 1D, located south of the DRMO compound, encountered the Goodland Limestone at 23 feet. Wells 1B and 1C were completed flush to the ground surface, in meter boxes. Wells 1A and 1D were completed above ground.

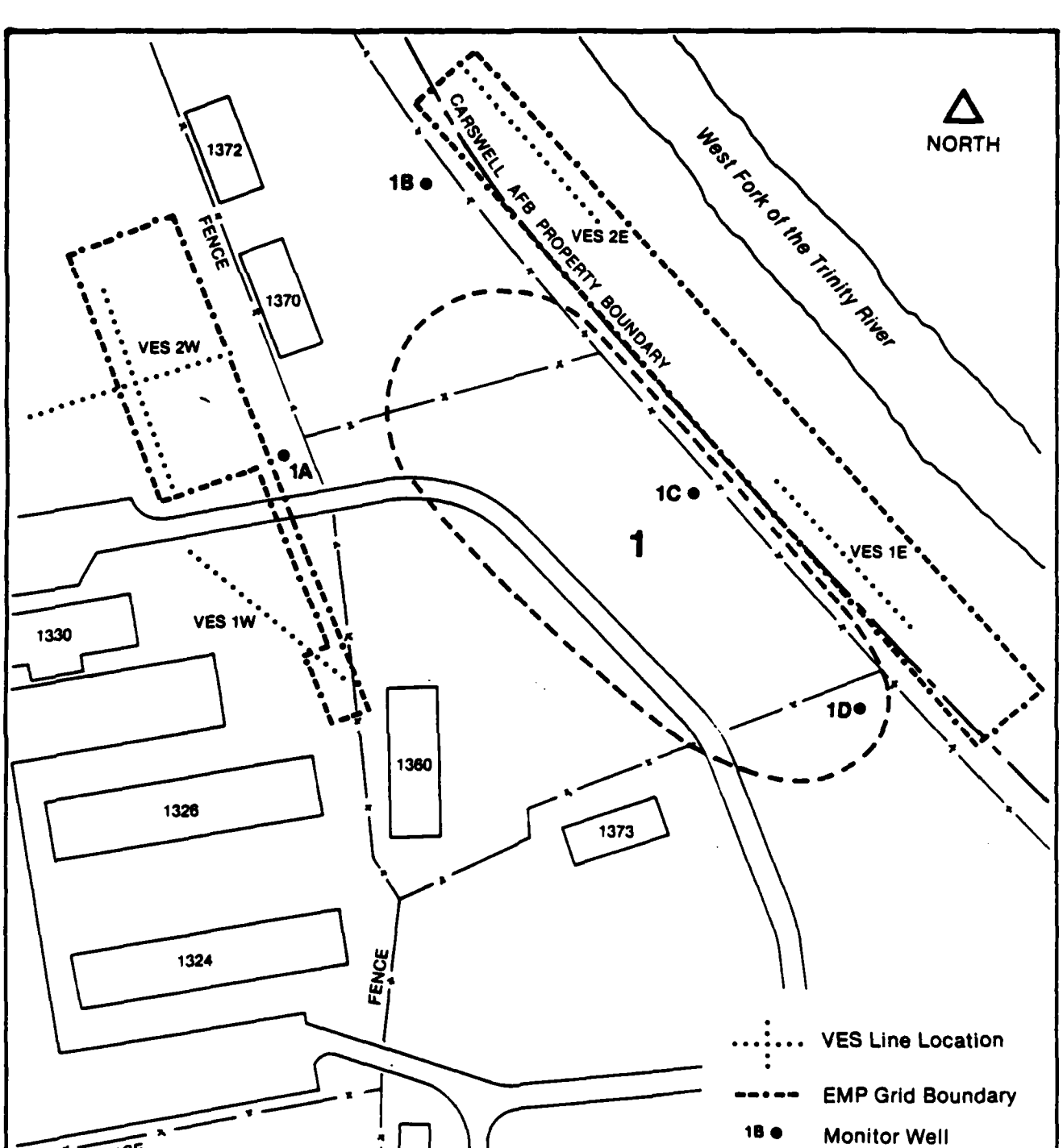

Figure 4-23. Location of Monitor Wells and Geophysical Surveys: Landfill No. 1 (Site 1), Carswell AFB, Texas.

Topography

Site 1 is located on a gently sloping terrace immediately west of the West Fork of the Trinity River. Elevations range from approximately 567 feet outside the west boundary of the DRMO compound to approximately 560 feet on the levee above the river.

Geologic Features

The upper zone deposits encountered during drilling at Site 1 are different than those encountered elsewhere in the East area. The material beneath Site 1 is finer grained, consisting entirely of fill, clay, and sandy clay. The sand and gravel layers penetrated in the other East area wells and borings are absent beneath the DRMO. The large amount of fill material (asphalt, concrete, tar, wood chips) encountered in the clay beneath the DRMO indicates that the area has been extensively modified by human activities. This evidence, and considering that sand and gravel layers pinch out from both the dip and strike oriented directions (Figures 4-18 and 4-19), suggests that the upper zone materials at the DRMO are the result of construction fill or rechanneling of the Trinity River.

The surface of the Goodland Limestone dips relatively steeply to the east beneath Site 1 (Figure 4-21), reflecting channel cutting and erosion of the limestone by the West Fork of the Trinity River. The land surface elevation does not dip eastwards as steeply as the limestone; therefore, the lower elevation of the top of the Goodland at wells 1B, 1C, and 1D accounts for the relatively greater thicknesses of alluvium at these wells as compared to the other wells in the East area.

Geophysical Surveys

Geophysical surveys directly over Landfill 1 were not feasible because of the large amount of cultural interference (buildings, large metal

objects stored at the DRMO). The degree of interference would have made a magnetometer survey useless, so that method was not used at the site. Electromagnetic profiling (EMP) and earth resistivity (VES) surveys were conducted on both the east and west sides of the DRMO. The results are presented in Appendix K, and are summarized below.

The grid for the EMP surveys consisted of two sections located on the flanks of the DRMO yard. The east section is located outside the base on the terrace deposits overlooking the West Fork of the Trinity River. The west section is located in the park outside the DRMO, with an extension running next to the U-Fix-It shop and housing facilities. The ground conductivity was read using the Geonics EM31 and EM34-3, allowing measurement of apparent conductivities of material at three depths depending on dipole orientation and electrode spacing.

The results of the EMP surveys are shown graphically on Figure 4-24. Four areas of anomalously high conductivity are apparent. Anomaly 1, on the west grid, is probably due to a nearby electrical line and anomaly 4 is due to the presence of a metal fence. Anomalies 2 and 3 on the east grid are not associated with any visible surface interference and may be due to fluid migration from the landfill. Anomaly 3 could also be associated with fluids migrating from the barrel containment area located south of the DRMO.

The VES data appear to be distorted because of nearby chain-link fences, with the result that low resistivity values are shown. The best data, on the west side of Landfill 1, are interpreted as showing an overburden thickness of approximately 4.3 feet. These data are fairly consistent with the results of drilling operations.

Occurrence of Ground Water

The depth to water at Site 1 ranges from almost 8 feet to almost 23 feet below land surface. The elevation of the water table is contoured in

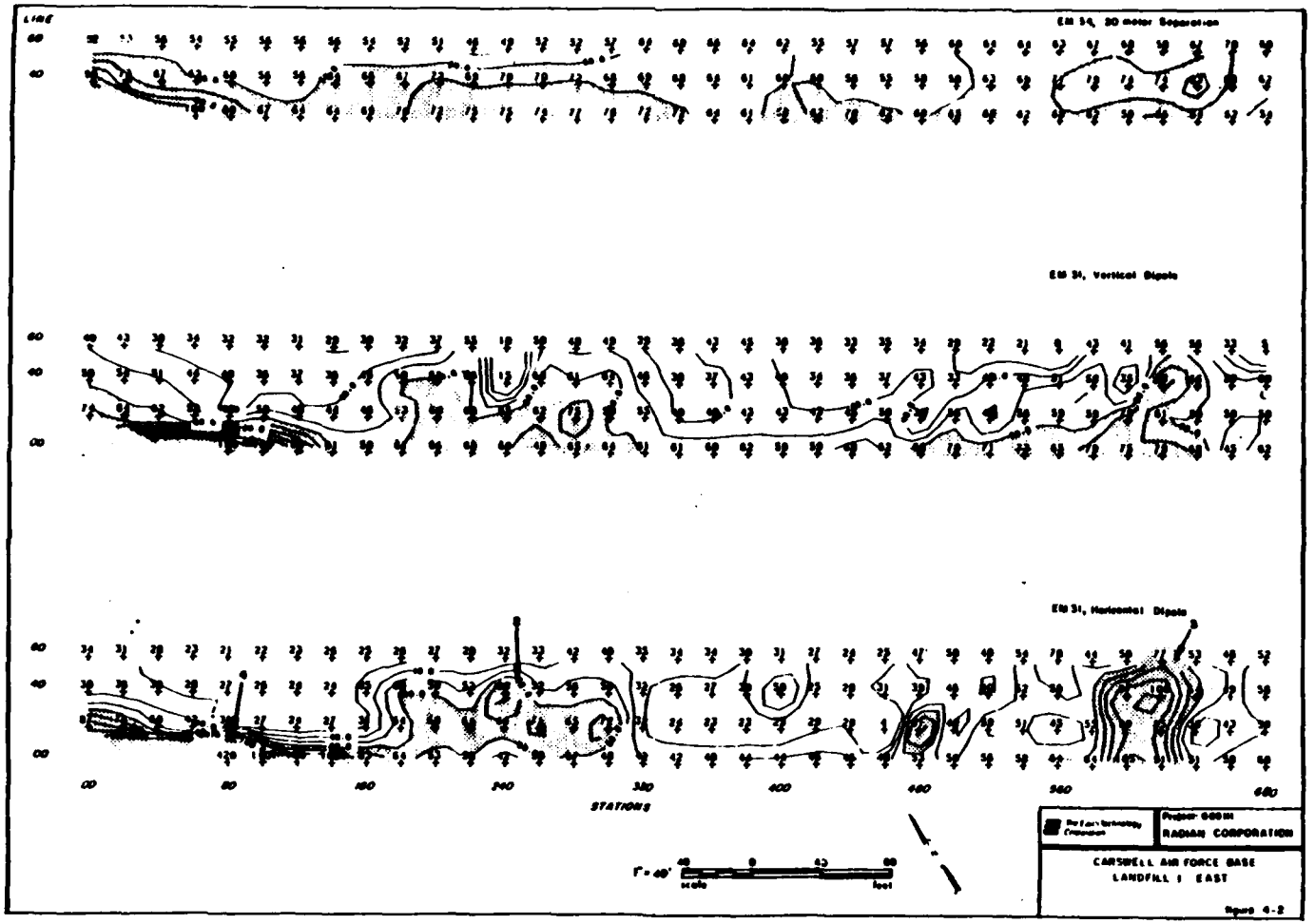

Figure 4-24. Electromagnetic Profile Date (EM31), Landfill No. 1 (Site 1), East, Carswell AFB, Texas.

Figure 4-22. The closely spaced contours of the water table in the DPDO area mirrors that of the surface of the Goodland Limestone. This similarity in limestone and water table surfaces is expected because the water in the upper zone is perched on top of the Goodland. Ground-water flow beneath Site 1 is eastward to northeastward, directly to the West Fork of the Trinity River.

Well 1B did not produce sufficient water to analyze for all of the constituents desired. Water was noted in the sediments of 1B at a depth of 9 feet during drilling, so the screened interval between 10 and 20 feet below surface was believed to intercept the uppermost 10 feet of water. The water levels of wells 1C and 1D suggest that well 1B was completed at too shallow a depth to encounter the main body of water in the upper zone, accounting for the almost dry nature of the well.

Though well 1D contained sufficient water for all required sampling, the time for water-level recovery in well 1D was markedly longer than the recovery time for well 1C. The difference in recovery time is best explained by the sandier nature of the clay encountered in well 1C as compared to 1D. Though both wells are completed in clay layers, the permeability of the clay at well 1C is substantially higher than that of the clay around well 1D.

Soil Chemistry and Water Quality

Samples of ground water were collected and analyzed from the four monitor wells in February and March 1985. A sample was collected from well 1B only during the March trip due to the extremely slow recovery rate of the well. In addition to the water samples, soil samples were collected and analyzed from all of the wells during drilling. Soil and water samples were analyzed for heavy metals, organic indicators, herbicides, insecticides, purgeable halocarbons, and purgeable aromatics. The results of these tests are presented in Tables 4-20 and 4-21, and are summarized in the following paragraphs.

TABLE 4-20. RESULTS OF SOIL SAMPLE ANALYSES, LANDFILL 1, CARSWELL AFB, TX

Parameter	BORING[1] 1A (4-5 ft)	1B (9-10 ft)	1B (19-20 ft)	1C (14-15 ft)	1C (24-25 ft)	1D (9-10 ft)	1D (19-20 ft)	1D (20 ft)
METALS (ug/g)								
Arsenic	<3.0	<3.0	<3.0, <3.0	<3.0	<3.0	<3.0	<3.0	11
Barium	16	40	49, 41	25	23	48	18	17
Cadmium	<0.39	<0.39	<0.40, <0.40	<0.40	<0.40	<0.39	<0.39	<0.40
Chromium	1.8	22	6.3, 6.5	4.3	5.4	5.7	8.9	8.0
Lead	<4.0	8	10, 8	<4.0	<4.0	8	5	8
Mercury	<0.05	0.13	0.10, 0.11	0.12	0.17	0.08	0.07	0.08
Selenium	<4.0	17	16, 12	10	<4.0	12	7	7
Silver	1.1	1.8	1.7, 1.4	1.4	1.4	1.0	2.1	2.1
ORGANIC COMPOUNDS (ug/g)								
Oil and Grease	71	76	210, 68	130	84	<10	85	<10
Phenols	<0.1	<0.1	<0.1, <0.1	<0.1	<0.1	<0.1	<0.1	<0.1
HERBICIDES[2] (ug/L)								
2,4-D	ND	ND	ND, ND	ND	ND	ND	0.52	ND
PESTICIDES[2] (ug/Kg)	ND	ND	ND, ND	ND	ND	ND	ND	ND
PURGEABLE HALOCARBONS[2] (ug/Kg)	ND	ND	ND, ND	ND	ND	ND	ND	ND
PURGEABLE AROMATICS[2] (ug/Kg)	ND	ND	ND, ND	ND	ND	ND	ND	ND

[1]Duplicate field samples are reported.
[2]Parameters shown were detected (ND = not detected).

TABLE 4-21. RESULTS OF GROUND-WATER SAMPLE ANALYSES, LANDFILL 1, CARSWELL AFB, TEXAS

Parameter	MONITOR WELL[1] 1A Feb	1A Mar	1B[2] Feb	1B[2] Mar	1C Feb	1C Mar	1D Feb	1D Mar
METALS (mg/L)								
Arsenic - ICP	<0.06	<0.06, <0.06	Not	<0.06	<0.06	<0.06	<0.06, <0.06	<0.06
Barium	0.34	0.21, 0.21	Sampled	0.28	0.18	0.18	0.088, 0.11	0.12
Cadmium	<0.002	<0.002, <0.002		<0.002	<0.002	<0.002	<0.002, <0.002	<0.002
Chromium	<0.005	<0.005, <0.005		<0.005	<0.005	<0.005	<0.005, <0.005	<0.005
Lead - ICP	<0.06	<0.06, <0.06		<0.06	<0.06	<0.06	<0.06, <0.06	<0.06
Mercury	0.0006	<0.0002, <0.0002		0.0006	0.0004	0.0003	<0.0002, 0.0005	<0.0002
Selenium - ICP	<0.06	<0.06, <0.06		<0.06	<0.06	<0.06	<0.06, <0.06	<0.06
Silver	<0.002	<0.002, <0.002		<0.002	<0.002	<0.002	<0.002, <0.002	<0.002
METALS (mg/L) - AA (resampled November 1988)								
Arsenic		0.012				0.006		0.006
Lead		<0.002				0.003		<0.002
Selenium		<0.003				<0.003		<0.003
ORGANIC INDICATORS (mg/L)								
Oil and Grease	170, 190	<1, <1		Not	<1	<1, <1	63, 63	<1
Phenols	0.074	<0.005, <0.005		Sampled	0.026	<0.005	0.039, 0.059	0.01
TOC	3	11, 9			3	7	7, 8	11
TOX	<0.01	0.01, 0.01			<0.01	0.09, 0.07	<0.01, <0.01	0.01
HERBICIDES[3] (ug/L)								
2,4,5-T	ND, ND	ND, ND			ND	ND, ND	ND, 0.2	ND
PESTICIDES[3]	ND, ND	ND, ND			ND	ND, ND	ND, ND	ND
PURGEABLE HALOCARBONS[3] (ug/L)								
Trichlorofluoromethane	ND, ND	3.4, 3.1		ND	ND, ND	ND, 3.1	ND, ND	3.8, 3.8
Trans-1,2-Dichloroethene	ND, ND	ND, ND		ND	0.8, 0.8	ND, ND	ND, ND	ND, ND
Trichloroethene	1.3, ND	ND, ND		ND	ND, ND	1.3, 1.4	ND, ND	ND, ND
PURGEABLE AROMATICS[3]	ND, ND	ND, ND		ND	ND, ND	ND, ND	ND, ND	ND, ND

[1] Duplicate field samples are reported.
[2] Well 1B was partially sampled due to extremely low yield of water.
[3] Parameters shown were detected (ND = not detected).

Heavy Metals The quantities of all heavy metals tested in the ground water at Site 1 were within acceptable limits according to the Primary Drinking Water Standards (Table 4-1). Soil analyses reveal relatively elevated amounts of selenium in wells 1B, 1C, and 1D, and higher amounts of arsenic and silver in well 1D than from other wells. There are no generally accepted standards or regulations governing heavy metal content in soil. A listing of the normal range in concentration of metals found in soils is given in Table 4-3. Natural occurrences of heavy metals can be far above or below the given normal range, depending on the geologic conditions in the soil's source area. The metals listed above as being 'relatively elevated' in the soil at Site 1 have concentrations above the normal range listed on Table 4-3. In addition to those metals, the levels of chromium and lead in soil from well 1B, and the level of lead in soil from 1C and 1D exceed the apparent background concentrations found at Site 1, based on the other sample analyses, but are not above the normal range on Table 4-3.

Organic Indicators Concentrations of oil and grease, phenols, total organic carbon values, and total organic halogen values were elevated in ground water samples from Site 1 monitor wells. Oil and grease were detected in high concentration (>50 mg/L) in water collected in February, 1985, from wells 1A and 1D. Phenols (>0.02 mg/L) were also detected in wells 1A, 1C, and 1D in February. Oil and grease and phenol concentrations were low in all of the samples taken from these wells in March, 1985. Water from 1D contained a slightly higher concentration of total organic carbon than wells 1A and 1C in February, but the TOC values of all of the wells were higher in March. The extremely slow recovery rate of well 1B prevented water from that well from being sampled for organic indicators; however, soil samples analyzed from well 1B had high concentrations (>50 ug/g) of oil and grease. Soil samples from the other wells also had high values for oil and grease. The differences in oil and grease values between soil and water may be attributed to variability in the sample media.

Herbicides and Insecticides The herbicide 2,4,5-T was detected in ground water from well 1D, and 2,4-D was detected in soil from the 19 to 20 foot interval in well 1D. No herbicides were detected in either the water or soil of the other wells, and insecticides were not detected in any wells at Site 1.

Purgeable Halocarbons Trichlorofluoromethane was detected during the March, 1985, sampling of wells 1A, 1C, and 1D. Trans-1,2-dichloroethene was detected in well 1C in February, 1985. Trichloroethylene was detected in well 1A in February, and in well 1C in March. No purgeable halocarbons were detected in soil samples from wells at Site 1.

Purgeable Aromatics Purgeable aromatic compounds were not detected in either the soil or water from wells at Site 1.

Significance of Findings

Results of the Phase II investigation show that Landfill 1 is underlain by a relatively thick section of apparently reworked sandy clay, in turn underlain by the Goodland Limestone. The upper surface of the Goodland dips steeply toward the West Fork of the Trinity River, probably due to erosion of the limestone by the river. Perched water occurs above the limestone, and, following the dipping limestone surface, moves through the sandy clay to the Trinity River.

A wide variation in oil and grease values was noted between water samples collected in February and in March, 1985. Both the soil analyses and the February water analyses show high oil and grease values, but the March water analyses show low oil and grease values. If the high values recorded in February reflect usual conditions, there may be two sources for oil and grease contamination. Well 1A's location adjacent to an unlined drainage ditch suggests that the oil and grease detected at 1A may be from street runoff. The pavement at the DRMO precludes any recent surface source for the oil and

grease in the soil at wells 1B and 1C. At these wells, oil and grease may be due to either the downgradient movement of oil and grease observed at well 1A, or it may originate at Landfill 1. At well 1D, elevated levels of oil and grease could also be due to infiltration of runoff from a barrel containment area just upslope of well 1D.

The concentrations of heavy metals in the ground water around Landfill 1 are within federal drinking water standards. However, metals in the soils downgradient of the landfill suggest that there has been some leakage from materials buried at the site. Water and soil from well 1D were also the only Site 1 samples in which herbicides were detected and water from 1D had a higher TOC content than the other site wells.

The source for the phenols detected in wells 1A, 1C, and 1D is unknown. The highest value for phenols was in the ground water from well 1A, and is presumably related to discharge through the nearby drainage ditch.

All concentrations of purgeable halocarbons in ground-water samples were quite low, usually at instrument detection limits. The source of the trans-1,2-dichloroethene in water from well 1C and TCE in water from wells 1A and 1C is unknown.

4.2.2.2 Site No. 13, Flightline Drainage Ditch

The investigation of Site 13 consisted of six hand-augering six borings and collecting of 3 surface sediment samples. Sample locations are shown on Figure 4-25. The borings were spaced evenly along the Flightline Drainage Ditch between where the ditch emerges east of Haile Drive and to where the ditch becomes concrete lined as it enters the POL Tank Farm. The surface sediment samples were evenly spaced across the same area.

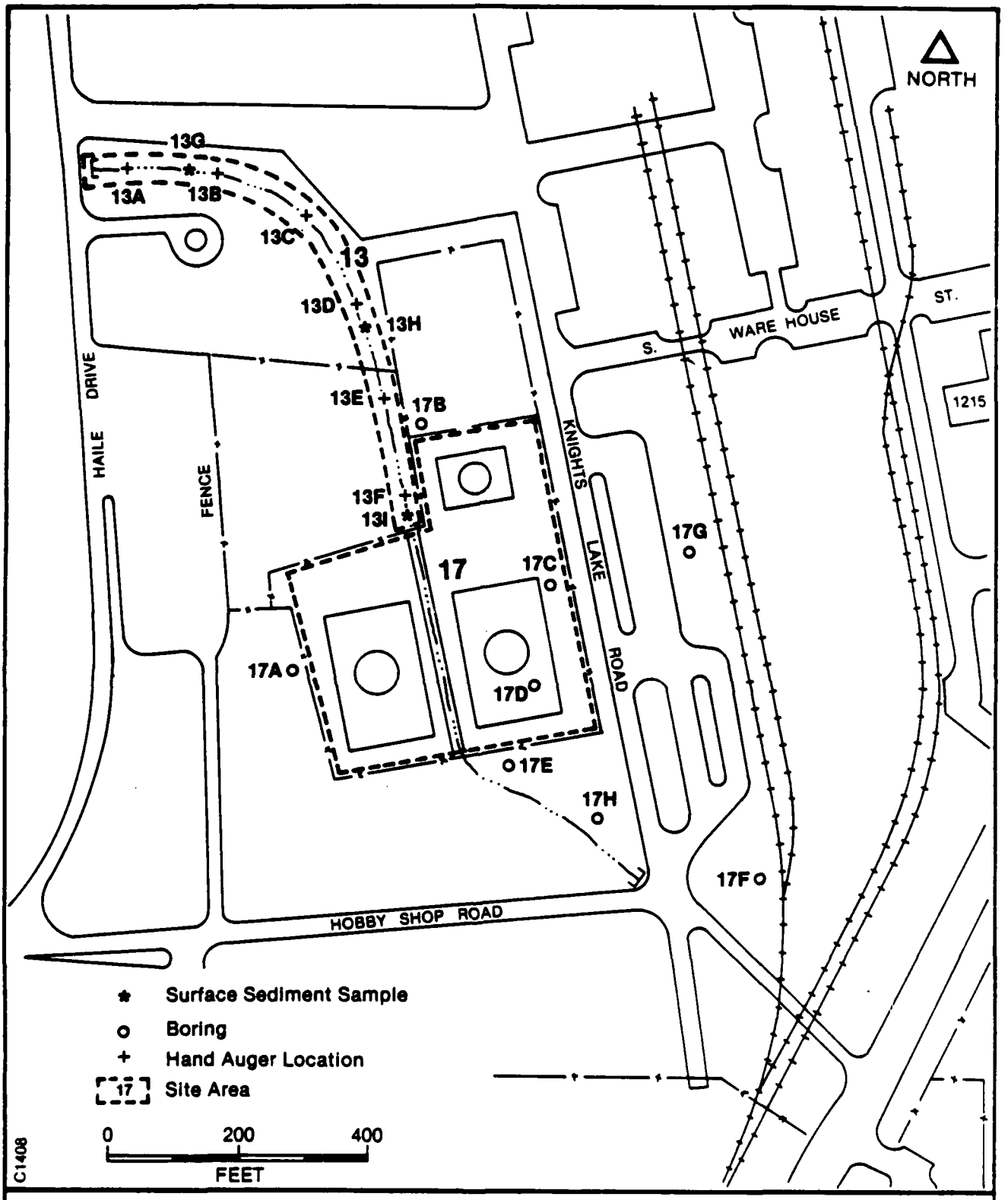

Figure 4-25. Locations of Sampling Points; Flightline Drainage Ditch (Site 13) and POL Tank Farm (Site 17), Carswell AFB, Texas.

Topography

The land surface in the area of Site 13 slopes in a generally east to southeastward direction. Elevations range from approximately 585 feet msl to almost 575 feet msl. The ditch itself lies approximately 5 feet below land surface.

Geologic Features

The borings at Site 13 extended a maximum of 10 feet below the surface, so only the most shallow sediments have been examined. In general, the soil is gravelly and hard. A very stiff clay is also present in the area. Some gravels along the ditch, especially in the vicinity of Boring 13E, were stained with a black, oily substance. The staining occurred at a depth equivalent to the observed stream level in the Flightline Drainage Ditch.

Occurrence of Water

Water occurs in the shallow sediments below the Flightline Drainage Ditch at depths between 6 inches and 4 feet below the surface. This water level is substantially higher than that in nearby borings (e.g. a water level of 16 feet in Boring 17B) and probably represents near-surface soil saturation related to the ditch, rather than the local ground-water body. At the time of sampling, stream flow in the ditch was estimated to be 0.05 cubic feet per second.

Soil Chemistry and Water Quality

No water samples were collected from the Flightline Drainage Ditch. However, 24 soil samples were collected and analyzed from borings and surface sediment samples along the ditch. Boring location 13F actually represent two borings augered in approximately the same location because the first soil samples were not large enough for metals analyses to be performed. The soils

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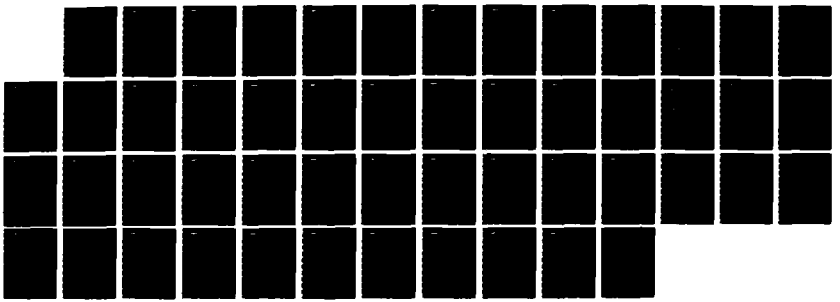

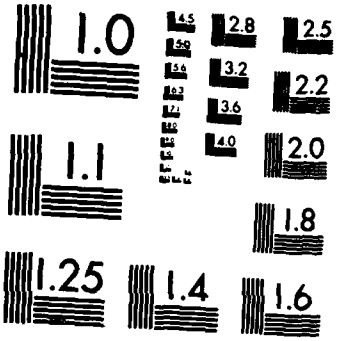

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were tested for heavy metals and oil and grease. The results of these analyses are presented in Table 4-22 and are summarized in the following paragraphs.

Heavy Metals No generally accepted standards exist regarding the heavy metal content of soils. Comparisons to the normal range of heavy metals concentrations found in most soils (Table 4-3) reveals that the concentration of metals in the Site 13 samples falls below average amounts. However, internal comparisons among all of the drainage ditch samples shows that some soils contain slightly higher metals concentrations than other nearby soil samples. For example, the cadmium concentrations in surface samples from borings 13B, 13C, and 13F are higher than for the other soil samples. Also, the mercury concentration is relatively high at the 4 foot depth in boring 13C. Boring 13D contained relatively elevated levels of chromium at the four foot depth and mercury at the 6 feet depth. The surface sample from 13F also contains slightly higher amounts of mercury.

Despite the anomalies mentioned above, the most pronounced change in heavy metal content occurs in the sediment sample collected at the southern end of the unlined portion of the Flightline Drainage Ditch. This sample, 13I, has much higher concentrations of arsenic, lead, mercury, selenium, and silver than any of the other samples.

Organic Indicators Many of the surface soil samples from along the ditch contain high levels (>50 ug/g) of oil and grease. However, the distribution of high and low values (Figure 4-26) does not reveal any pattern of contamination. For instance, the oil and grease values in excess of 500 ug/g at borings 13A and 13D are separated by the <10 ug/g value at 13B and the 60 ug/g at 13C. The highest oil and grease values are found between 2 and 8 feet deep in boring 13F. The difference in oil and grease concentrations in surface samples at 13F is likely due to sample variability. Boring 13F is the southernmost boring in the ditch, just before the ditch becomes concrete lined.

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TABLE 4-22. RESULTS OF SOIL SAMPLE ANALYSES, FLIGHTLINE DRAINAGE DITCH, CARSWELL AFB, TX

Parameter	BORING 13A (0 ft)	13B (0 ft)	13B (2 ft)	13B (4 ft)	13C (0 ft)	13C (2 ft)	13C (4 ft)	13C (6 ft)
METALS (ug/g)								
Arsenic	<0.06	<0.06	<0.06, <0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Barium	1.1	1.0	0.8, 1.0	0.91	0.89	0.68	0.72	0.45
Cadmium	<0.002	0.003	<0.002, <0.002	<0.002	0.031	<0.002	<0.002	<0.002
Chromium	<0.005	0.008	0.007, <0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Lead	<0.06	<0.06	<0.06, <0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Mercury	0.0008	0.0007	0.0004, 0.0008	0.0008	0.0008	0.0008	0.0016	0.0006
Selenium	<0.06	<0.06	<0.06, <0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Silver	<0.002	<0.002	<0.002, <0.002	<0.002	<0.002	<0.002	<0.002	<0.002
ORGANIC COMPOUNDS (ug/g)								
Oil and Grease	810	<10	<10, <10	<10	60	<10	<10	<10

(Continued)

TABLE 4-22. (Continued)

Parameter	BORING 13D (0 ft)	13D (2 ft)	13D (4 ft)	13D (6 ft)	13D (8 ft)	13E (0 ft)	13F (0 ft)	13F (0 ft)
METALS (ug/g)								
Arsenic	<0.06	<0.06	<0.06	<0.06	<0.06	-	-	<0.06
Barium	1.1	1.2	0.78	0.66	0.54	-	-	0.88
Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002	-	-	0.03
Chromium	<0.005	<0.005	0.014	0.006	<0.005	-	-	<0.005
Lead	<0.06	<0.06	<0.06	<0.06	<0.06	-	-	<0.06
Mercury	0.0008	0.0004	0.0004	<0.0002	0.0011	-	-	0.0016
Selenium	<0.06	<0.06	<0.06	<0.06	<0.06	-	-	<0.06
Silver	<0.002	<0.002	0.005	<0.002	<0.002	-	-	<0.002
ORGANIC COMPOUNDS (ug/g)								
Oil and Grease	660	<10	<10	<10	<10	60	30	<10

(Continued)

TABLE 4-22. (Continued)

Parameter	BORING 13F (2 ft)	13F (2 ft)	13F (4 ft)	13F (6 ft)	13F (8 ft)	13G SS	13H SS	13I SS
METALS (ug/g)								
Arsenic	-	<0.06	-	-	-	<0.06	-	0.19
Barium	-	0.94	-	-	-	0.38	-	0.37
Cadmium	-	<0.002	-	-	-	<0.002	-	0.007
Chromium	-	<0.005	-	-	-	<0.005	-	0.022
Lead	-	<0.06	-	-	-	<0.06	-	0.12
Mercury	-	0.0004	-	-	-	0.0008	-	0.13
Selenium	-	<0.06	-	-	-	<0.06	-	0.18
Silver	-	<0.002	-	-	-	<0.002	-	0.027
ORGANIC COMPOUNDS (ug/g)								
Oil and Grease	1300	50	2000	160	1400	<10	270	69

SS = Surface Sediment.

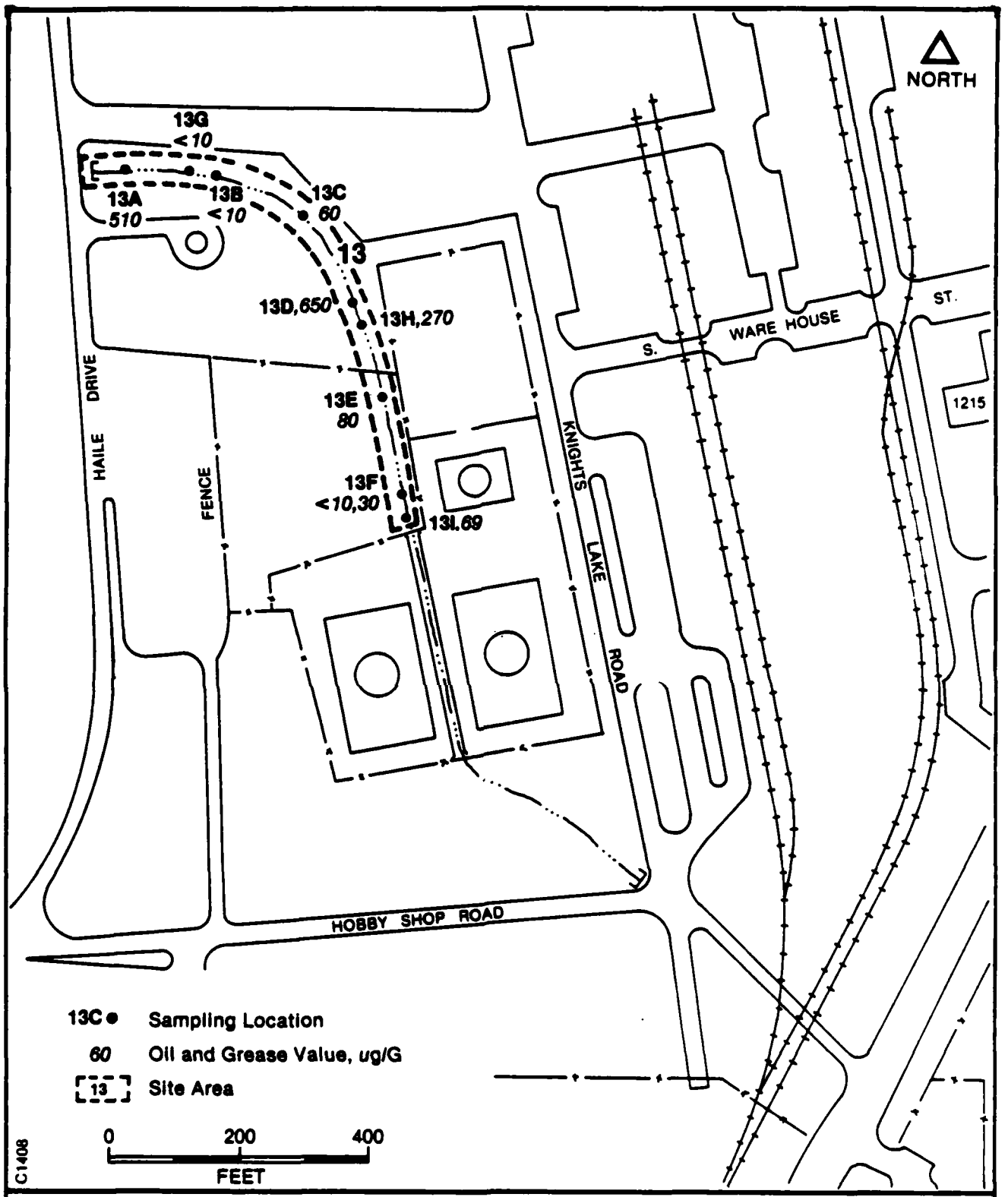

Figure 4-26. Oil and Grease of Surface Soils, Flightline Drainage Ditch (Site 13), Carswell AFB, Texas.

Significance of Findings

The Flightline Drainage Ditch is underlain by hard, gravelly soil. Water occurs in the ditch and in the shallow sediments adjacent to the ditch as a result of seepage. The soils along the ditch show signs of organic contamination, based on their oil and grease contents. Note that the oil and grease analysis actually measures all freon-soluble material, including soaps and detergents, as well as hydrocarbons. Therefore, the oil and grease measured in the ditch soils could be from either detergents draining from the flightline washracks, from JP-4 released from the Fuel Systems Shop, or both.

The relatively high heavy metals and oil and grease values in soils at the southern end of the Flightline Drainage Ditch are unexplained. Water may pool in this area, just prior to entering the concrete-lined portion of the ditch, allowing for more infiltration of contaminants into the soil. Another possibility is that there may be a second source of contaminants introduced into the southern portion of the ditch. The large difference in heavy metals contents favors the possibility of a second source, because metals readily adsorb onto sediment surfaces and should be more evenly distributed along the channel.

4.2.2.3 Site 15, Entomology Dry Well

Site 15 is located in the area of Building 1337, east of Rogner Drive near the Main Gate (Figure 4-27). The upgradient well, 15A, is located north of Building 1337. This well was completed flush to the ground surface in a meter box. Well 15B is located south of Building 1337, next to the fence along the eastern boundary of the site. Well 15C is West of 15B; both were completed above ground. Both of these wells are near the former location of Buildings 1313 and 1338. Well 15A encountered a shale of the Goodland Limestone at 14 feet below ground surface and the well was completed at that depth. Wells 15B and 15C both penetrated the Goodland at approximately 9 feet below land surface and were completed at a depth of 10 feet.

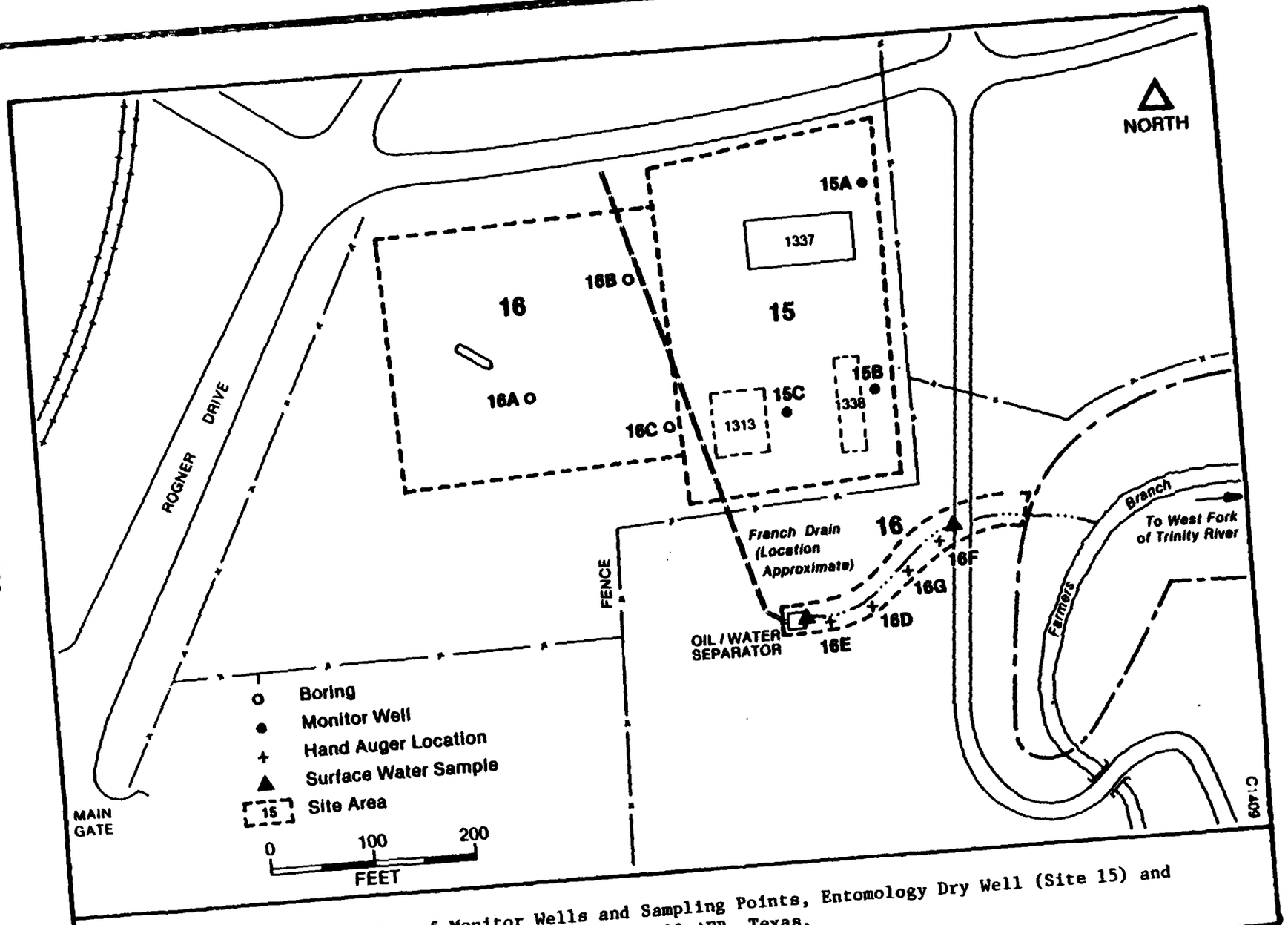

Figure 4-27. Location of Monitor Wells and Sampling Points, Entomology Dry Well (Site 15) and Unnamed Stream (Site 16), Carswell AFB, Texas.

Soil Chemistry and Water Quality

Samples of ground water were collected and analyzed from the three monitor wells established during the Phase II field program. Samples were collected both in February, 1985, and again in March, 1985. The water samples were analyzed for total organic carbon, herbicides, and insecticides. Soil samples were collected during the drilling of the monitor wells and were analyzed for herbicides and insecticides. Results of the ground-water quality analyses are reported in Table 4-23.

A sample was also to have been collected from the Entomology Dry Well, located at Site 15. Unfortunately, the location of the well has been obscured by both the demolition and construction of buildings in the Site 15 area and subsequent re-grading of the land surface. Although efforts were made by Carswell AFB personnel to locate the well, the search was not successful and no sample was collected.

Organic Indicators The total organic carbon content of the water samples does not indicate the presence of any substantial amounts of organic compounds. The TOC values are lowest at well 15C and highest at well 15B. No tests for organic compounds were performed on the soil samples.

Herbicides and Insecticides Water collected from well 15C in February, 1985, contained less than 0.1 ug/L each of the insecticides Lindane and Endrin. No other herbicides or insecticides were detected in water from well 15C. All other water and soil samples contained no detectable traces of either insecticides or herbicides.

Significance of Findings

Results of the Phase II investigation show that Site 15 is underlain by clayey soil and sand and gravels of alluvial origin. Beneath the alluvium are the limestone and shale of the Goodland Formation. The upper surface of

TABLE 4-23. RESULTS OF GROUND-WATER SAMPLE ANALYSES, SITE 15, CARSWELL AFB, TX

Parameter	MONITOR WELL 15A Feb	15A Mar	15B Feb	15B Mar	15C Feb	15C Mar
ORGANIC INDICATORS (mg/L)						
TOC	3	4	4	5	<1	2
HERBICIDES[1] (ug/L)	ND	ND	ND	ND	ND	ND
INSECTICIDES[1] (ug/L)						
Lindane	ND	ND	ND	ND	<0.1	ND
Endrin	ND	ND	ND	ND	<0.1	ND

[1]Parameters shown were detected (ND = not detected).

the Goodland dips down to the south, toward Farmers Branch. Water occurs in the sand and gravel, perched on top of the Goodland. Water movement is toward Farmers Branch, which discharges into the West Fork of the Trinity River approximately 2000 feet downstream.

The former presence of the Entomology Building and the Entomology Dry Well have apparently not affected the quality of ground water in the area of Site 15.

4.2.2.4 Site 16, Unnamed Stream

Site 16 is located to the south and west of Site 15 (Figure 4-27). It is divided into two parts: the Unnamed Stream from the oil/water separator to Farmers Branch, and the paved lot in the vicinity of an abandoned gasoline service station near Site 15. The investigations near the Unnamed Stream consisted of the collection of soil samples from three hand-augered borings and of water samples from the oil/water separator and a point near the confluence of the Unnamed Stream and Farmers Branch. Investigations in the paved lot included a geophysical survey and the drilling of three soil borings. Boring 16A is located to the southeast of the suspected position of the abandoned gas station. The boring was completed at 13.5 feet below land surface, one foot below encountering the Goodland Limestone. Boring 16B is located approximately 100 feet west of Building 1337. Boring 16B was completed upon reaching limestone at 13 feet. Boring 16C is located approximately 100 feet south of Boring 16B. Boring 16C had a total depth of 8 feet, the same depth as the Goodland Limestone.

Geological Features

The upper zone beneath Site 16 includes 2 to 7 feet of clay and fill material. Beneath the clay is 5 to 7 feet of sand and gravel. The sand is brown to gray and coarsens downward into gravel. The surface of the limestone

beneath Site 16 is nearly level, though there is a slight slope to the northwest.

Geophysical Survey

The purpose of the magnetometer survey at Site 16 was to identify if buried tanks existed below the ground at the site. The tanks may have been left behind when the gasoline station was abandoned. Three magnetic anomalies are present on the map produced from the survey (Figure 4-28). Anomaly 1, located beneath the pump island, is probably due to steel reinforcement of the concrete pad. Though there is the possibility that the tanks are located beneath the pad, most gasoline stations position tanks away from the service pumps for safety and convenience. Anomalies 2 and 3, located southwest and northeast of the pump island, have no obvious source and one or both may represent the buried tanks. The presence of at least two distinct highs at anomaly 3 suggests that this is the tank location because most gasoline stations have two to three tanks, located close together. Though the configuration of the yard at the time the gasoline station was operating is not known, the location of anomaly 3 was probably more accessible to tank trucks, and thus more likely as the tank location. However, anomaly 2 is also very distinct and cannot be ruled out as a possible tank location on the basis of the magnetometer data.

Occurrence of Water

Water in the Unnamed Stream emerges from the oil/water separator. Water enters the separator from a french drain which was installed to aid the removal of fuels from the ground either at the POL Tank Farm (Site 17) or at the abandoned gasoline station. Whatever the source, the Unnamed Stream is a perennial stream feeding into Farmers Branch.

Ground-water levels were estimated on the basis of water encountered during the drilling of the soil borings. Water was encountered between 7 and

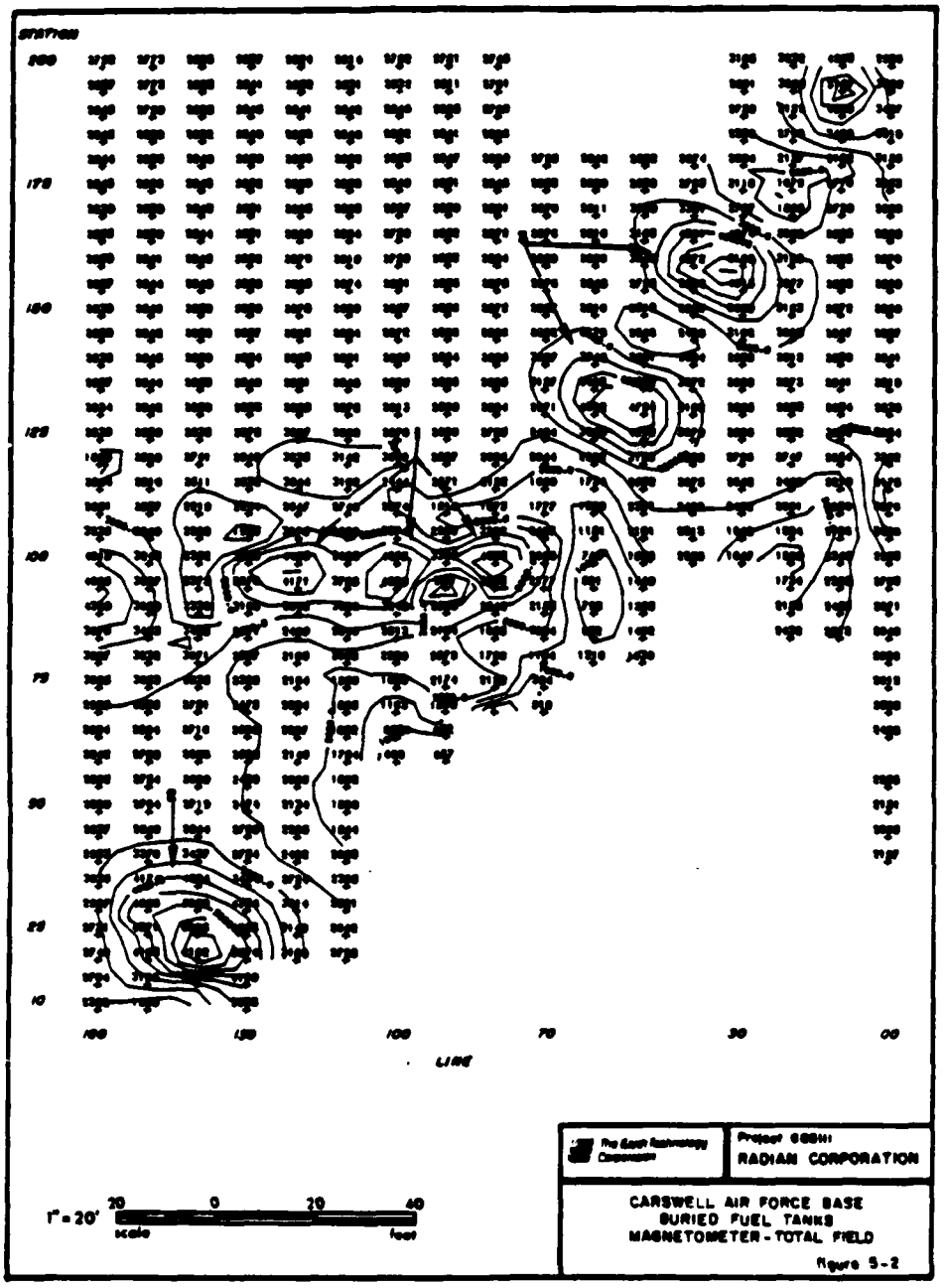

Figure 4-28. Results of Magnetometer Survey, Unnamed Stream (Site 16), Carswell AFB, Texas.

10 feet below land surface. The estimated ground-water elevations range from 558 to 560 feet msl. The ground-water surface dips slightly to the south, with water flow toward Farmers Branch.

Soil Chemistry and Water Quality

Samples of ground water were collected and analyzed from borings 16A, 16B, and 16C. Surface water samples were collected in both February and March, 1985, from the oil/water separator and from the Unnamed Stream. The collection point from the Unnamed Stream was immediately upstream from the point where the unpaved road crosses the stream. Soil samples were collected from four hand-augered borings located along the Unnamed Stream. The locations of the samples are shown on Figure 4-27. Water and soil samples were analyzed for heavy metals, organic indicators, purgeable halocarbons, and purgeable aromatics. The surface water samples were also analyzed for insecticides and herbicides. The results of these tests are presented in Table 4-24 and 4-25, and are summarized in the following paragraphs.

Heavy Metals Ground water from borings 16A and 16C contain levels of barium in excess of federal Primary Drinking Water Standards (Table 4-1). Water from the oil/water separator contains arsenic and lead above the levels listed in the Primary Drinking Water Standards. Though not in excess of standards, the cadmium and chromium content of water in the oil/water separator is high relative to that of the other Site 16 water samples.

Soil samples from all hand-augered borings had values for selenium higher than the range usually found in soils. In addition, the lead content of shallow soil samples (0-2 feet) is at the high end of the normal range and higher than the lead content of most of the other soils analyzed from Carswell AFB.

Organic Indicators The presence of high amounts of organic compounds is indicated by high oil and grease and TOC values in both ground and

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TABLE 4-24. RESULTS OF SOIL SAMPLE ANALYSES, UNNAMED STREAM (SITE 16), CARSWELL AFB, TEXAS

Depth (ft) / Parameter	BORING 16D (0-2 ft)	16E (2 ft)	16E (8 ft)	16F (1 ft)	16F (9 ft)	16G (0-2 ft)
METALS (ug/g)						
Arsenic	11	9.9	6.1	<5.8	<6.1	7.0
Barium	48	85	74	45	57	58
Cadmium	0.70	0.89	0.56	0.19	<0.2	0.55
Chromium	7.1	13	8.6	4.6	5.1	5.5
Lead	19	20	13	3.6	8.4	18
Mercury	0.08	0.10	0.10	0.09	0.05	0.09
Selenium	20	41	24	9.5	9.1	16
Silver	1.2	1.2	1.2	0.56	0.82	0.8
ORGANIC COMPOUNDS (ug/g)						
Oil and Grease	44	61	240	<10	27	56
PURGEABLE AROMATICS[1] (ug/g)						
Toluene	ND	ND	ND	ND	0.540	ND
PURGEABLE HALOCARBONS[1] (ug/g)	ND	ND	ND	ND	ND	ND

[1]Parameters listed were detected (ND = not detected)

TABLE 4-25. RESULTS OF WATER SAMPLE ANALYSES, UNNAMED STREAM (SITE 16), CARSWELL AFB, TX

Parameter	GROUND WATER FROM BORINGS			SURFACE WATER[1]			
				Oil/Water Seperator		Unnamed Stream	
	16A	16B	16C	Jan	Feb	Jan	Feb
METALS (mg/L)							
Arsenic - ICP	<0.08	<0.08	<0.08	0.16	<0.08	<0.08	<0.08
Barium	1.3	0.86	1.2	0.29	0.28	0.25	0.25
Cadmium	<0.002	<0.002	<0.002	0.007	<0.002	<0.002	<0.002
Chromium	<0.005	<0.005	<0.005	0.017	<0.005	<0.005	<0.005
Lead - ICP	<0.080	<0.080	<0.080	0.081	<0.08	<0.080	<0.08
Mercury	0.0004	0.0008	0.0004	0.0003	0.0004	0.0005	0.0004
Selenium - ICP	<0.080	<0.080	<0.080	<0.080	<0.08	<0.080	<0.08
Silver	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
METALS (mg/L) - AA (resampled November 1985)							
Arsenic					0.056		0.042
Lead					<0.002		<0.002
Selenium					<0.003		<0.003
ORGANIC INDICATORS (mg/L)							
Oil and Grease	940	<1	7100	640	1	<1	<1
TOC	230	1	420	200	4	4	4
TOX	0.01	<0.01	<0.01		0.01		0.04
PURGEABLE HALOCARBONS (ug/L)							
Trichlorofluoromethane	4.2	ND	ND	ND	2.9	ND	3.3
Trans-1,2-Dichloroethane	0.1	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	2.9	ND	ND	ND	ND	ND
Tetrachloroethylene	ND	ND	ND	ND	ND	ND	3.4
PURGEABLE AROMATICS (ug/L)	*[2]	high[3]	very high[3]	ND	ND	ND	ND

[1] The surface water samples were also analyzed for herbicides and pesticides, but neither was detected.
[2] Sample bottle broken during storage.
[3] Both samples 16B and 16C contained large amounts of organic contaminants, but the amounts could not be quantified due to interference.

surface water. Water from boring 16B does not contain appreciable amounts of any organic indicators, but water from both 16A and 16C contain large amounts of oil and grease and high TOC values. Surface water in the Unnamed Stream was found to be relatively free of organic indicators in February, but contained a relatively elevated amount of total organic halogens in March. Water collected from the oil/water separator was found to have high amounts of oil and grease and total organic carbon in February, but almost none in March.

Oil and grease values were found to be high in almost all of the soil samples analyzed from the Unnamed Stream. The concentrations are highest closest to the oil/water separator (boring 16E) and generally decrease with distance downstream. The oil and grease content increases with depth in boring 16E.

Herbicides and Insecticides The analysis of surface water did not reveal the presence of herbicides or insecticides in the Unnamed Stream or in the oil/water separator. Ground water and soil samples were not analyzed for these substances.

Purgeable Halocarbons Trichlorfluoromethane was detected in the ground water from boring 16A, and in the March surface water samples from the Unnamed Stream and oil/water separator. TCE is present in water from boring 16B and tetrachloroethylene was detected in the Unnamed Stream in March. Trace quantities of trans-1,2-dichloroethane were also noted in water from boring 16A. No purgeable halocarbons were detected in soil samples collected near the Unnamed Stream.

Purgeable Aromatics The ground water at Site 16 contains large amounts of purgeable compounds. Water from both borings 16B and 16C registered high amounts of unsaturated purgeable compounds beyond the six aromatics analytes listed in EPA Method 602. Water from boring 16A could not be analyzed for purgeable aromatics because the sample bottle broke before the

surface water. Water from boring 16B does not contain appreciable amounts of any organic indicators, but water from both 16A and 16C contain large amounts of oil and grease and high TOC values. Surface water in the Unnamed Stream was found to be relatively free of organic indicators in February, but contained a relatively elevated amount of total organic halogens in March. Water collected from the oil/water separator was found to have high amounts of oil and grease and total organic carbon in February, but almost none in March.

Oil and grease values were found to be high in almost all of the soil samples analyzed from the Unnamed Stream. The concentrations are highest closest to the oil/water separator (boring 16E) and generally decrease with distance downstream. The oil and grease content increases with depth in boring 16E.

Herbicides and Insecticides The analysis of surface water did not reveal the presence of herbicides or pesticides in the Unnamed Stream or in the oil/water separator. Ground water and soil samples were not analyzed for these substances.

Purgeable Halocarbons Trichlorfluoromethane was detected in the ground water from boring 16A, and in the March surface water samples from the Unnamed Stream and oil/water separator. TCE is present in water from boring 16B and tetrachloroethylene was detected in the Unnamed Stream in March. Trace quantities of trans-1,2-dichloroethane were also noted in water from boring 16A. No purgeable halocarbons were detected in soil samples collected near the Unnamed Stream.

Purgeable Aromatics The ground water at Site 16 contains large amounts of purgeable compounds. Water from both borings 16B and 16C registered high amounts of unsaturated purgeable compounds beyond the six aromatic analytes listed in EPA Method 602. Water from boring 16A could not be analyzed for purgeable aromatics because the sample bottle broke before the

analysis was performed. Purgeable aromatics were not detected in the surface water samples.

Soil from boring 16F, at the nine foot depth, contains a substantial amount of toluene. No purgeable aromatics were detected in the other samples.

Significance of Findings

Results of the Phase II Stage 1 investigation show that Site 16 is underlain by clay, sand, and gravel of alluvial origin that rests on the southerly dipping surface of the Goodland Limestone. The sand and gravels beneath Site 16 seem to be laterally continuous, providing a permeable pathway for the movement of perched water on top of the relatively impermeable limestone. Water movement is southward, toward Farmers Branch.

Heavy metals in the Site 16 area appear to be related to discharge from the oil/water separator. High metals concentrations were found in the water in the separator and in the soils downstream from the separator. However, metals contamination was not found in the Unnamed Stream. The adsorption of metals onto the sediments of the Unnamed Stream is apparently an effective mechanism for removing the metals from the stream water. The removal of many heavy metals from solution is enhanced by the presence of hydrous iron oxide. Metals such as arsenic, cadmium, chromium, lead, selenium, and silver either coprecipitate with or adsorb onto hydrous iron oxide. The presence of iron oxide staining and heavy metals in the sediments along the source of the Unnamed Stream and the disappearance of metals from solution between the oil/water separator and the stream suggest that the coprecipitation/adsorption process is active in the stream sediments.

Contamination from organic compounds appears to be significant in the ground water at Site 16. The high levels of purgeable organic compounds measured in the ground water indicate that the organic contamination is probably from fuels. Both samples of ground water at borings 16B and 16C contained large amounts of purgeable organic compounds, but the amounts could

not be quantified due to interference. Given the conditions near the site, the fuels could be from one or both of the following sources: 1) a spill at the former gasoline station or leakage from buried tanks associated with the station; or 2) leakage from the POL Tank Farm. The french drain feeding the oil/water separator was installed due to a gasoline leak at the former base gasoline station. However, the oil and grease and TOC values for water inside the separator (collected on the inflow side) were not as high as those detected in the ground water. This suggests that either the contamination has not reached the drain in mass yet, or it is moving downgradient to Farmers Branch and bypassing the drain. The highly permeable nature of the sand and gravel deposits at the site could be reducing the effectiveness of the french drain in rerouting flow.

Very little oil and grease was detected in the water of the Unnamed Stream, but sediments collected from borings along the stream contained oil and grease. The pattern of decreasing oil and grease with distance downstream from the separator suggests that flow from the separator is the source for the oil and grease in the soils. The presence of toluene, found in gasoline, in one soil sample may be related to fuels escaping from the separator.

Sources for the TCE in water from boring 16B and the tetrachloroethylene in the Unnamed Stream are unknown, but may be related to the fuel occurrences already discussed. Solvent usage at the service station may also be a former source.

4.2.2.5 Site 17, POL Tank Farm

The POL Tank Farm is located between Knights Lake Road and Haile Drive, north of Hobby Shop Road. Eight soil borings were drilled in and around the tank farm area (Figure 4-25). Caution was necessary in the placement of the borings because of the presence of underground fuel lines. All boring locations were cleared through the Carswell AFB Civil Engineering office before drilling began.

The upgradient boring, 17A, was located just to the west of the fence surrounding POL Tank 1156. This boring had a final depth of 20 feet and did not strike the Goodland Limestone. Boring 17B is located north of the tank farm and was also 20 feet deep and completed above the Goodland. Boring 17C was located inside the fenced POL compound, northeast of Tank 1157, and between two natural gas lines. Boring 17C did not reach the Goodland Limestone and was completed at a depth of 20 feet. Boring 17D was located inside the berm of the tank 1157, on the southeast side, and was 20 feet deep. Boring 17D was located south of Tank 1157, next to the Flightline Drainage Ditch. Limestone was encountered in 17E at 20 feet below the surface. Boring 17F was between Building No. 1172 and the railroad tracks. This boring was completed upon reaching the Goodland Limestone at 17.5 feet. Boring 17G was located within the pumping station between structures number 1168 and 1169. This boring was 17 feet deep, the same depth as the limestone. Boring 17H was located near the northwest corner of Knights Lake Road and Hobby Shop Road, close to the Flightline Drainage Ditch. This boring encountered limestone at 16.5 feet and was completed at this depth.

Geological Features

The upper zone in the POL Tank Farm area typically consists of 10 feet of gray to tan clay, followed by another 5 to 10 feet of sand and gravel. The clay often has minor limonite staining and contains pebbles and freshwater gastropod shells. The sand is gray, tan to brown, or pink in color, and is generally fine-grained. Gravel ranges from pea size to pebbles over an inch in diameter.

The depth to the Goodland Limestone beneath the POL Tank Farm ranges from 17 to over 20 feet below land surface. Where the elevation of the limestone is known, it maintains a fairly level surface at approximately 555 feet msl.

Occurrence of Water

Water levels beneath Site 17 were estimated during borehole drilling by both measuring the depth to water and noting the saturation state of soil samples. The depth to water at Site 17 varies from approximately 9.5 feet to 16 feet. Water level elevations range from 560 to 571 feet msl. The water surface slopes primarily from west to east across most of the Tank Farm; however, the slope turns to the southeast across the eastern portion of Site 17, diverting water flow in the upper zone away from the Trinity River and toward Farmers Branch.

Soil Chemistry and Water Quality

Samples of ground water were collected and analyzed from the eight borings drilled in the POL Tank Farm Area. Soil samples were also collected and analyzed from all of the boring during drilling. Water samples were analyzed for oil and grease, TOC, and TOX. Soil samples were analyzed for oil and grease. The results of these tests are presented in Table 4-26 and 4-27 and are summarized in the following paragraphs.

Organic Indicators The presence of abnormally high amounts of organic compounds is indicated in the water from all of the Site 17 borings by the content of TOC. TOC values range from 44 to 190 mg/L. The TOC content of water in the upper zone elsewhere on base is usually below 4 mg/L. Though TOC values are uniformly high, there is no correlation with the oil and grease values. This apparent contradiction is the result of interference in the laboratory analysis of oil and grease for samples 17A, 17B, 17C, 17F and 17H. The source of the interference is unknown, but the result was the recording or unreliable, low values. The samples in which interference did not occur have very high oil and grease values. The highest value was recorded in water from boring 17E, which contained 31,000 mg/L oil and grease. The water from boring 17D, in addition to having high oil and grease and TOC values, also has a much higher TOX content than the other samples.

TABLE 4-26. RESULTS OF SOIL SAMPLE ANALYSES, POL TANK FARM (SITE 17), CARSWELL AFB,TX

	BORING												
Depth (ft)	17A (0-10)	17A (14-16)	17B (0-10)	17B (10-20)	17C (0-10)	17C (14-16)	17D (14-16)	17E (0-10)	17E (14-16)	17F (14-16)	17G (0-10)	17G (14-16)	17H (14-16)
ORGANIC INDICATORS													
Oil and Grease (ug/g)	170	170	<10	<10	<10	<10	<10	1300	170	<10	810	<10	<10

TABLE 4-27. RESULTS OF GROUND-WATER ANALYSES, POL TANK FARM, CARSWELL AFB, TX

	BORING							
Parameter	17A	17B	17C	17D	17E	17F	17G	17H
ORGANIC INDICATORS (mg/L)								
Oil and Grease	<1*	<1*	<1*	5800	31,000	<1*	10,000	<1*
TOC	77	180	100	78	44	100	80	85
TOX	0.01	<0.01	<0.01	0.12	<0.01	0.01	<0.01	<0.01

*Value not reliable, interference suspected in analysis.

The analysis of soil samples revealed high oil and grease contents in soils from borings 17A, 17E, and 17G. The highest oil and grease concentration recorded was in soil from the 9 to 10 foot depth in boring 17E. During drilling, an oily sludge was noted in a thin gravel stringer encountered in boring 17G and Draeger tube reactions were noted in borings 17D, 17E, and 17.

Significance of Findings

Results of the hydrogeologic investigation at Site 17 reveal that the area is underlain by an approximately ten feet thick layer of clay and sandy clay and 5 to 10 feet of sand and gravel. The Goodland Limestone occurs at a depth of approximately 20 feet. Water occurs perched above the Goodland at depths between 10 and 16 feet. Water movement is from west to east across the western Site 17 area, but flow turns in the eastern area to become primarily from northwest to southeast. This bend in potentiometric contours diverts flow away from the West Fork of the Trinity River and toward Farmers Branch. Cross sections of the East area show continuous permeable sand/gravel beds from the POL Tank Farm to near Farmers Branch, suggesting that water flow is unimpeded from the POL Tank Farm area to Farmers Branch.

The uniformally high TOC values for all of the Site 17 samples indicates that organic contamination is widespread in the POL Tank Farm area. Based on the TOC and oil and grease values, the degree of contamination is severe. There may be more than one source for the observed organics. According to the potentiometric map, water from borings 17A and 17B should not have moved through the POL Tank Farm Area. However, TOC analyses reveal that water from both of these borings contained high levels of organics. In fact, the highest TOC value recorded from Site 17 water samples was from 17B. Another anomaly occurs at boring 17D, which has a much higher TOX content than the other water samples.

The source of the organics at 17A is unknown, but may be related to either subsurface flow from the hanger area, or the presence of a solid waste collection site between 17A and Haile Drive. The contamination at 17B is likely to be related to infiltration of materials in the unlined portion of the Flightline Drainage Ditch, located just west of the boring. The organics in the water and soil of the other borings are most likely related to activities at the POL Tank Farm, though there may also be contributions from the Flightline Drainage Ditch and the unknown source upgradient of 17A. In particular, the very high oil and grease concentrations detected in both the soil and water of boring 17E may be related to the Flightline Drainage Ditch. Though the ditch is concrete-lined as it passes by 17E, underflow beneath the lining, previous cracks in the concrete, or previous unlined ditch conditions may account for the oil and grease at 17E. The high TOX content of water at 17D suggests that organic solvents, as well as fuels, are entering the perched water at the POL Tank Farm.

The high TOC content in water at 17F, located downgradient of the POL Tank Farm, indicates that contamination from the tank farm is migrating down the hydraulic gradient toward Farmers Branch. The french drain located at Site 16 was reportedly built to intercept fuels lost in a leak from the POL Tank Farm. Based on the potentiometric contour map, it is unlikely that the drain will intercept flow from the POL Tank Farm. Though water level data are limited, it appears that the organics from the tank farm will enter Farmers Branch upstream of Site 16, without having passed through the oil/water separator at the end of the french drain.

4.2.3 Weapons Storage Area Investigation

Work performed at the Weapons Storage Area (WSA) consisted of two main activities: the collection of a ground-water sample from the water supply well and hand augering of three shallow borings. The results of these investigations are discussed in the following paragraphs.

Geologic Features and Soils Investigation

The WSA is located on the outcrop of the Fredericksburg and Washita Groups. The Paluxy sand is at the surface where the limestone has been eroded. The potable water well at the WSA is reportedly screened in the Paluxy aquifer and the Twin Mountains Formation.

The three borings performed west of the Inspection Shop (Figure 4-29) encountered sandy clay with variable amounts of fine to coarse sand and limestone gravel. An indurated layer, probably limestone, was encountered at shallow depths. Two borings were completed in a shallow drainage just west of the concrete parking area. Limestone was encountered at depths of 3.25 feet and 2.5 feet. A third boring, completed to a depth of 5 feet, was located adjacent to the concrete pad where runoff enters the drainage ditch. Ground water was encountered at a depth of 5 feet, coinciding with a gravelly sand layer.

Soil Chemistry and Ground-Water Quality

Three hand-augered borings were performed west of the Inspection Shop (Bldg. 8503) in order to determine the impact of the suspected disposal of waste cleaners and solvents in the shop area. A total of six samples were collected; the borings were terminated upon reaching indurated sandstone or limestone at shallow depths. In addition, a sample of water was obtained from the supply well in order to determine the radiochemical properties of the water. Results of the soil analyses are provided on Table 4-28.

The results of soil analyses show relatively low levels of oil & grease, with only one sample showing 0.0619 ug/g of TCE. The samples with TCE was collected at a depth of 3.25 feet at the upstream locating in the drainage ditch. Purgeable aromatic compounds were not detected in any soil samples.

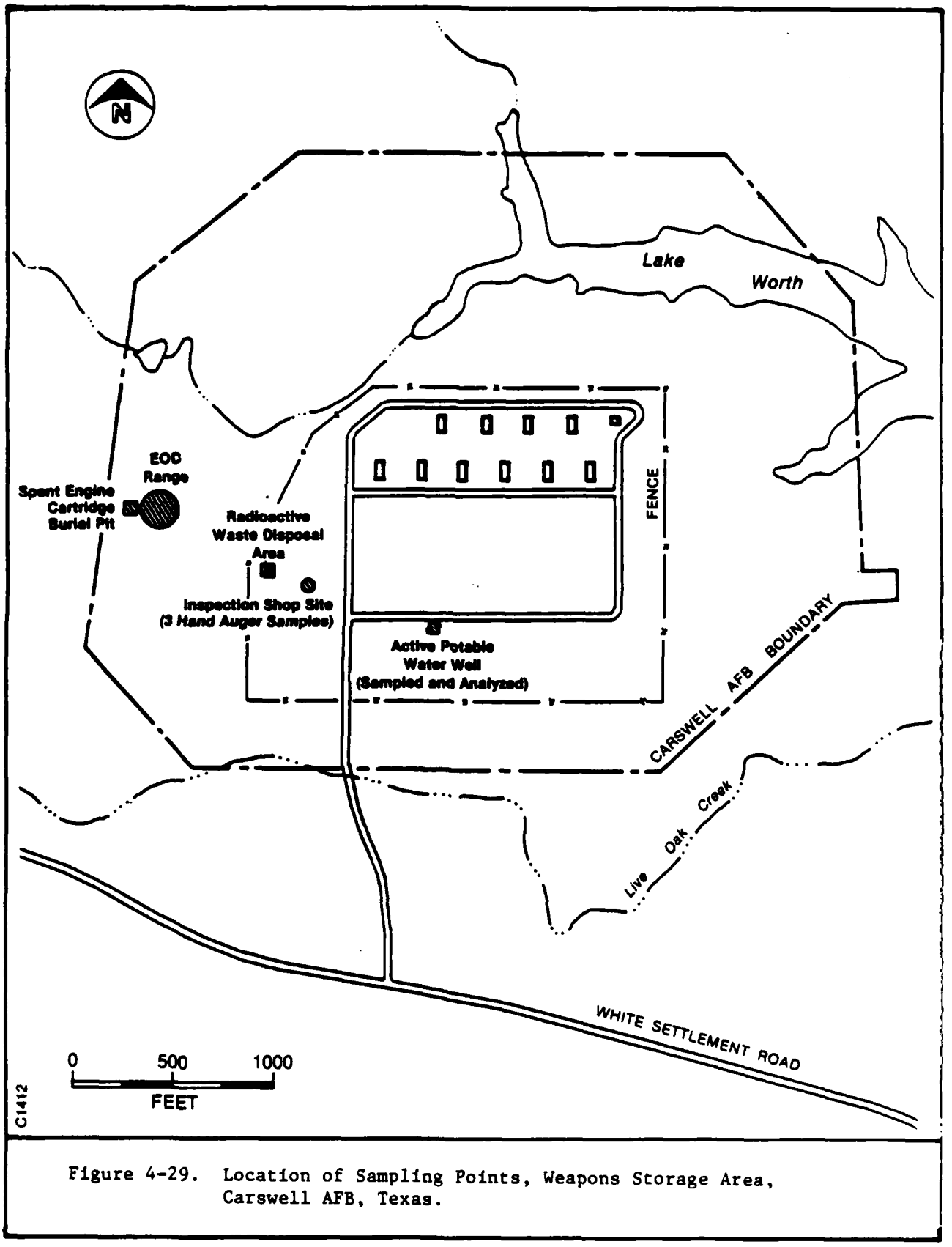

Figure 4-29. Location of Sampling Points, Weapons Storage Area, Carswell AFB, Texas.

RADIAN

TABLE 4-28. RESULTS OF SOIL SAMPLE ANALYSES, WEAPONS STORAGE AREA, CARSWELL AFB, TEXAS

Parameter	BORING					
	Drainage Ditch (upslope)		Drainage Ditch (downslope)		Concrete Pad	
	(1.5 ft)	(3.25 ft)	(1.5 ft)	(2.5 ft)	(1.5 ft)	(ft)
ORGANIC INDICATOR (ug/g)						
Oil & Grease	<10	<10	14	<10	<10	<10
PURGEABLE HALOCARBONS (ug/g)						
Trichloroethylene	ND	0.0619	ND	ND	ND	ND
PURGEABLE AROMATICS (ug/g)						
	ND	ND	ND	ND	ND	ND

Note: ND = not detected

The sample of ground water collected from the potable supply well was analyzed for radionuclides. Results of the analysis are as provided in Table 4-29.

Significance of Findings

Results of the soil analyses appear to confirm the information in the Phase I records search (CH2M Hill, 1984) that small quantities of waste cleaners and solvents were disposed of on the ground just west of the inspection shop site. The finding of TCE in only one sample from one boring also suggests that the occurrence of TCE is not widespread. In addition, TCE was not detected immediately downslope in samples from an adjacent soil boring. Any contaminant in the soil would be expected to migrate vertically downward until a low permeability zone or the water table is encountered. The limited investigation at the Inspection Shop has revealed both an indurated layer at shallow depth and the presence of ground water less than 5 feet below the land surface. It is not known whether this occurrence of water represents the main water table or merely a thin saturated interval perched on the indurated layer encountered in other borings.

Analysis of water from the potable well has revealed fairly low levels of radionuclides in the ground water. Both results of Gross Alpha and Gross Beta indicate levels lower than the federal drinking water standards (see Table 4-1). Analyses of the potable water supply by the base have shown results of less than 5.0 pCi/L radium. However, results of the Total Radium (Radium 226 and 228) analysis indicates that the level of radium is higher than the drinking water standard of 5 pCi/l.

TABLE 4-29. RESULTS OF GROUND-WATER SAMPLE ANALYSIS, WEAPONS STORAGE AREA, CARSWELL AFB, TEXAS

Parameter	Concentration*
Gross Alpha	3.6 (1.5)
Gross Beta	5.1 (1.8)
Total Radium	8.5 (0.9)

*Units are in pCi/L; values in parentheses represent +/-one standard deviation at 68% confidence level.

5.0 ALTERNATIVE MEASURES

This section presents a discussion of the alternate measures that may be applied to the sites that were investigated as part of the Phase II Stage 1 work at Carswell AFB. The alternate measures presented in this section are based on the geophysical, hydrogeologic, and analytical findings discussed in Section 4.0.

The following paragraphs describe the major possible options for dealing with each site. Generally speaking, there are two classes of options (other than clean-up or other remedial actions) that are available at each site. These options include: no further action, appropriate in the case where available evidence does not suggest the potential for environmental impairment; and further monitoring, appropriate for sites where possible problems have been incompletely identified.

5.1 Flightline Area

It is appropriate to consider alternate measures for each flightline site both individually and cumulatively. The common hydrogeologic setting, similarity of identified problems, and physical proximity of the sites to each other suggest that any alternate measures for individual sites should also recognize neighboring sites and the corresponding options. Therefore, the possible options for the flightline area sites are first identified site-by-site, and then discussed within the context of the entire flightline area.

Landfill 3

Landfill 3 was the scene of geophysical surveys designed to determine the extent of the waste disposal area and indirectly determine the subsurface structure and lithology. This assignment was complicated by the presence of the main runway, which offered substantial interference with the electromagnetic and electrical resistivity equipment. Unlike the other

flightline sites, no direct measurements of the soil or ground water chemistry were obtained.

Given the remote location of Landfill 3 from the rest of the flightline sites and other environmental receptors (e.g., wells, streams, lakes), the environmental consequences of the "no action" option are relatively smaller than at the other sites. In addition, available records (CH2M - Hill, 1984) suggest that the site only received non-hazardous rubble and construction-related trash. Furthermore, it is highly unlikely that the area will undergo future disruption that would increase the presently small environmental risks.

The option for further investigations consists largely of the collection of soil samples, installation of ground-water monitor wells, and analysis of ground water. These actions would be very similar to the now-completed Phase II Stage 1 activities accomplished at the other flightline sites. There are several good technical reasons for further monitoring: soil and ground water chemistry are not defined, the occurrence of ground-water and the direction of flow are unknown, and the finding of ground-water contamination upgradient of the other flightline sites in the direction of Landfill 3 suggests that the two areas should be better integrated. In addition, recent hydrogeologic studies conducted at the east side of AF Plant 4 have determined that significant ground water contamination exists in the upper zone deposits and Paluxy aquifer (Hargis & Associates, 1985); this finding near the Carswell runway lends support to the option that the ground water conditions at Landfill 3 be better defined.

Landfill 4

Conditions at Landfill 4 consist of an area of ground water-contamination identified in the upper zone deposits east of the site. Of the five monitor wells installed in the upper zone, two wells revealed elevated levels of TCE and the other wells exhibited relatively low levels of a variety of

halogenated organic compounds. Analyses conducted at the Paluxy well revealed no trace of contamination. The Stage 1 findings support the conclusion that the contamination may move laterally downgradient toward Farmers Branch and the Trinity River and/or may migrate vertically downward to the Paluxy aquifer if discontinuities exist in the Goodland/Walnut aquitard.

Possible alternative measures include:

- Continued sampling and analysis of ground water from the existing upper zone and Paluxy wells;
- Installation and sampling of additional monitor wells; and
- No further action.

The results of sampling and analysis conducted during the Stage 1 work have confirmed the presence of organic contaminants in the upper zone east of the site. However, the limits of contamination, while better defined upgradient of the site owing to the proximity of Site 12 and the pinching out of upper zone deposits to the south, are not adequately defined downgradient (east) of Landfill 4. This finding suggests that the first two alternative measures listed, continued sampling and analysis in combination with further exploratory drilling and well installation, are appropriate responses to the Stage 1 results. The "no action" alternative is inappropriate considering the elevated levels of TCE in the upper zone and insufficiently defined ground-water flow system.

Landfill 5 and Waste Burial Area

Landfill 5 and the Waste Burial Area are considered together owing to their physical proximity and similarity of geology, hydrology, and water quality. Essentially, the Stage 1 work has determined that much of the upper zone ground water has elevated levels of TCE, both upgradient and downgradient

of the sites. Levels of contamination decrease, but do not disappear, in a northward direction, downslope and toward the unnamed tributary to Farmers Branch that forms the western and northern boundary of Landfill 5. Overall, the direction of ground water flow is to the east under a relatively low hydraulic gradient. Sampling and analysis of the upgradient upper Paluxy well just south of the landfill and west of the Waste Burial Area revealed no trace of contamination.

The possible alternative measures for these sites are as follows:

- o Continued sampling and analysis of ground water from the existing upper zone and Paluxy wells;
- o Installation and sampling of additional monitor wells; and
- o No further action.

While results of sampling and analysis conducted during the Stage 1 work have confirmed the presence of organic contaminants in the upper zone, the limits of contamination are not defined either upgradient or downgradient of the sites. These conclusions suggest that the first two alternative measures listed, continued sampling and analysis in combination with further exploratory drilling and well installation, are appropriate in view of the Stage 1 results. The "no action" alternative is inappropriate considering the elevated levels of TCE in the upper zone and insufficiently defined ground-water flow systems.

Fire Training Area 2

Results of soil and ground-water analyses conducted at Site 12 show high levels of halogenated and aromatic organic compounds centered at the site. In addition, observations during the drilling activities and analyses of unsaturated soil suggest that a vapor plume may also be present under

sections of the site. Thus, the Stage 1 investigation has identified that contamination exists but has not defined the complete limits or nature of the transport phenomena that may operate at the site.

As at the other flightline area sites, there are several alternate measures that may be selected. They are as follows:

- Continued sampling and analysis of ground water from the existing upper zone monitor wells;
- Installation and sampling of additional monitor wells; and
- No further action.

The hydrogeologic setting of Site 12 appears to be relatively well defined; geologic and water quality results from wells 12A and 12C suggest that upgradient conditions are defined, although the downgradient conditions of the site are limited by Landfills 4 and 5 and the Waste Burial Area. Several questions posed by the results of the Stage 1 work point to the need for additional data on the unsaturated zone downgradient (north and east) of the site, the occurrence and quality of ground water both closer to the center of the site and northeast of well 12B, and any possible seasonal variations in surface water quality that may affect recharge to upper zone water in the vicinity of Landfill 5. These considerations lead Radian to conclude that both continued sampling and analysis of existing wells and emplacement of additional data points in the form of wells and possibly soil borings are appropriate. As with the other flightline sites, the finding of significant levels of contamination preclude further exploring of the "no further action" alternative.

Fire Training Area 1

Results from Site 11 do not suggest levels of contamination that approach the elevated concentrations of TCE and other organic compounds south of the site. All reported findings of purgeable and aromatic halocarbons and herbicides are in low levels, suggesting a much lower priority on further investigation that necessary for the other sites.

Even recognizing the lower potential for environmental impairment at Site 11, there are three possible actions;

- Continued sampling and analysis of ground water from the existing upper zone wells;
- Installation and sampling of additional monitor wells; and
- No further action.

The absence of significant contamination at this site suggests a different approach for future work as compared to the southern flightline sites. The finding of very low levels of organic contaminants, along with the proximity to ground water with high levels of TCE, supports continued sampling and analysis of ground water at the existing two wells. However, there is no need to install additional wells in the vicinity of the site.

5.2 East Base Area

The occurrence of contaminants in the water and soil beneath the East Base area of Carswell AFB is important primarily in the context of threats to a receptor. The main receptor to be considered in the East Base area is the West Fork of the Trinity River. All of the sites in the East Base area have the potential to directly impact either the river or its tributary,

Farmers Branch. With this in mind, the alternative measures for each site are discussed in the following sections.

Landfill 1

Knowledge of the geology and ground-water levels at Landfill 1 is adequate to define the hydrogeologic environment at the site, and thus predict the movement of any contaminants from the landfill. However, the chemical quality of water beneath the site has not been precisely quantified due to the large differences between water analyses performed in February and March. The available alternative measures are:

- Assume that wide variations in oil and grease values represent seasonal fluctuations in water quality. Remedial measures could then be required to meet the conditions imposed by the high oil and grease values recorded in February.

- Conduct another sampling program to determine the extent of the contamination of upper zone water. This program may not absolute support either the February or March data, but should reveal whether relatively high amounts of oil and grease are common in water at Site 1, or if the February data record an anomalous event.

Radian recommends that the sampling program be conducted. All of the information needed can be acquired from samples collected from wells installed during the Phase II, Stage 1 field program. The unsupported acceptance of the existing data is technically unsound and could lead to instituting unnecessary remedial measures.

Flightline Drainage Ditch

The hydrogeologic environment at the Flightline Drainage Ditch was not the focus of the Phase II, Stage 1 work at this site, and thus has not been described in detail. Information gathered from other East area sites (e.g., POL Tank Farm) is probably adequate for understanding general flow directions from the Flightline Drainage Ditch. Chemical data clearly indicate the presence of contamination in the soil along the ditch, but the lack of water analyses leaves the water quality undefined. The available alternative measures are:

- Based on the soil analyses, and the water analysis from boring 17B, assume that contamination from the Flightline Drainage Ditch is moving into the water of the upper zone and institute corrective measures accordingly.

- Install upper zone monitor wells downgradient of the ditch to assess the impact of the ditch on water quality.

Radian recommends assuming that the ditch is having an adverse affect on water quality in the upper zone. The soil analyses from the ditch and the water analysis from 17B support this assumption. Remedial actions proposed to limit soil contamination (see Chapter 6) will also limit water contamination.

Entomology Dry Well

The hydrogeology and water quality of the former Entomology Building location have been adequately described by the Phase II, Stage 1 study. Water quality does not appear to have been affected by either pesticides or herbicides, though the dry well itself was not sampled. Given that the water of the upper zone does not presently contain contaminants related to the former presence of the Entomology Building, the alternative measures recommended are as follows:

- o Assume that the dry well poses no future threat to the site environment and cease actions at the site.

- o Assume that the dry well may pose a future threat to the site environment, but if a release of contaminants should ever occur, regular sampling and analysis of water from the three wells installed during the Phase II, Stage 1 investigation would alert the base to the problem.
- o Locate the dry well, sample its contents, and investigate the well's integrity in order to assess any threat the well may pose.

Radian recommends either of the last two options, though locating the dry well is the preferred course of action. Locating and sampling the dry well will clearly indicate to the base whether or not additional action is needed. It may be that a continued sampling program is unnecessary. However, if the contents of the well are deemed to pose a threat, removal and proper disposal of the contents of the well will be much simpler and cost-efficient than any remedial action necessary if the monitor wells detect contaminants.

Site 16, Unnamed Stream

The hydrogeology of Site 16 has been described on the basis of field data obtained during the Phase II, Stage 1, study but additional information is needed to precisely ascertain ground-water flow directions and the influence of the french drain on water movement beneath the site. Water collected from soil borings indicates the presence of large amounts of purgeable aromatic compounds, but the areal extent and exact nature the contamination is unknown. Considering that surface water quality in the Unnamed Stream is already monitored as one of the base Bioenvironmental Engineer's quarterly sampling points, the following alternative actions are available:

- o Install monitor wells at the site to provide additional and more-precise measurements of water levels and water quality. Ideally, these wells would be located not only in the vicinity of the soil borings already drilled, but also extend downgradient in order to try and delineate the extent of contaminant migration.

- o Precisely locate the french drain buried in the site area, gather any information existing on its construction and purpose and analyze the drain's impact on the transport of contaminants from Site 16.

- o Coordinating with Air Force personnel, the history of activity at the former gasoline station should be investigated to the highest degree possible. This investigation should include delineating the location of the gasoline station and its features, as well as identifying any spills or leaks associated with the station.

Radian recommends that all of the above alternatives be undertaken. The drilling and sampling program is vital to the success of any future remedial action program. Obtaining information on the french drain and former gasoline station may prove impossible due to the transfer of personnel, etc., but should be pursued as a relatively cost-effective method of gathering important site information.

POL Tank Farm

The geology beneath the POL Tank Farm has been sufficiently described based on the soil borings drilled during the Phase II, Stage 1 field program. The hydrogeology is fairly well described based on water levels measured in the borings before the holes were filled. The water quality has been definitely identified as being adversely affected by organic contamination,

presumably associated with the tank farm, though high TOC values in an upgradient well suggest the existence of two sources. The exact nature of the contamination and its areal extent have not been determined. The alternative measures recommended are as follows:

- Install monitor wells to allow for precise determination of water levels and the collection of repeated water samples. Analyses should be performed that will allow for the differentiation of various TOC and O&G compounds so that a determination can be made as to whether all of the contamination detected is from the same source. Wells should be located in the vicinity of the soil borings already drilled, as well as downgradient in order to delineate the areal extent of the contamination.

- Research the history of the fuel release that occurred in the 1960's from the tank farm and identify if any other such releases have occurred. This information may be difficult to retrieve due to the time elapsed, but could prove invaluable if the amount of the release can be determined.

Radian recommends that both measures be undertaken. The monitor well installation and sampling is imperative to determine the extent of the contamination detected in the Phase II, Stage 1 work. The spill history could prove to be valuable information for determining the appropriate remedial action, and should be obtained if possible.

5.3 Weapons Storage Area

Soil and ground-water analyses conducted at the WSA have revealed no significant levels of contamination. One soil sample taken from a hand-augered boring west of the Inspection Shop had TCE; however, there are no standards for soil to develop conclusions regarding the relative importance of

the TCE levels. The following alternative measures are available for consideration:

- Conduct periodic sampling of the potable water supply well for radionuclides. This measure is in response to acceptable values of gross alpha and gross beta, and an elevated level of total radium in the supply well.

- Install one or more ground-water wells west of the Inspection Shop in the area of the drainage ditch. The finding of TCE in one soil sample suggests that contamination may be present in the ground-water.

- No further action.

The results of the Stage 1 investigation point to a combination of the first two alternatives as being the most appropriate future actions at the site. Currently, no information is available regarding the occurrence and quality of shallow ground-water at the WSA. Chapter 6 contains specific recommendations for additional field investigations at the WSA.

6.0 RECOMMENDATIONS

This section contains the Phase II Stage 1 IRP recommendations for further actions at Carswell AFB. According to Air Force criteria, each site has been assigned to one of the following categories:

Category I - sites where no further action is required,

Category II - sites requiring additional monitoring or work to assess the extent of current or future contamination, and

Category III - sites that require and are ready for remedial action.

Most sites investigated during the Stage 1 program fall into Category II, requiring additional monitoring to better define and assess the extent and character of contamination. Every site investigated had evidence of some soil or ground-water contamination, precluding the identification of any Category I sites. Also, the hydrogeologic and chemical data for most sites was generally not sufficient to adequately define the physical environment to the extent required for the design and implementation of remedial actions. One site, the Flightline Drainage Ditch, is adequately characterized in order to begin design of corrective actions and was therefore assigned to Category III.

The following sections present the recommendations and basis for further action required for the Stage 1 sites. The sites are grouped by category, and within each category are presented in order of priority as shown on Table 6-1.

RADIAN

TABLE 6-1. PRIORITY OF RECOMMENDED STAGE 2 SITES AND ACTIONS, CARSWELL AFB, TX

Priority	Site(s)	Rationale'	Summary of Recommended Actions
Highest	Landfills 4, 5; Waste Burial Area; Fire Training Area 2	High TCE levels in groundwater	Install additional monitor wells to define contamination plume.
		Excessive benzene and toluene levels in soil	Determine if soil vapor plume is present.
		Continued opportunity for introduction of contamination	Define transmissivity of upper zone.
High	POL Tank Farm Unnamed Stream	High levels of organic compounds in ground water	Install monitor wells to define contaminant plume.
		Proximity of Farmers Branch	Define ground-water flow characteristics and upper zone transmissivity.
Middle/ Low	Entomology Dry Well; Landfills 1, 3; Fire Training Area 1 WSA	Minor or no ground-water contamination	Continue monitoring at existing wells.
		No ground-water data at Landfill 3	Install wells at Landfill 3.
		Proximity of Entomology Dry Well and Fire Training Area 1 to higher priority sites	Resample water well and analyze for radionuclids.
		Elevated total radium in water well	Install three upper zone wells to determine ground-water conditions.

6.1 Category II Sites

Category II sites are defined as sites requiring additional monitoring work or work to quantify or further assess the extent of contamination. The sites listed in Category II are: Landfills 1, 3, 4, 5; Waste Burial Area; Fire Training Areas 1 and 2; POL Tank Farm; Entomology Dry Well; and Unnamed Stream.

Site 1, Landfill 1

Results of ground water sampling and analysis at Landfill 1 are somewhat conflicting, with the suggestion that ground-water contamination may be present. The physical setting of the landfill, including the occurrence of ground water and the thickness and character of upper zone deposits, appears to be adequately characterized. It is also recognized that the landfill is adjacent to the Trinity River, which would be the receptor for any contamination that could migrate off-base. Accordingly, the following action is recommended:

- Conduct additional sampling at the four upper zone monitor wells in order to determine if contamination exists in the ground water. The presence of organic contaminants and heavy metals in water collected from the site in February, but the relative absence of these materials in March result, in this recommendation. Samples should be analyzed for purgeable organics, heavy metals, TOC, and oil and grease.

- Investigate the condition and contents of metal drums stored just south of the DPDO yard. Runoff from this storage area has the potential for introducing contaminants into the upper zone ground water.

- Perform aquifer tests (probably slug tests) on selected upper zone wells in order to determine the physical characteristics

(e.g., transmissivity) of the upper zone in order to support eventual design of remedial actions.

Site 3, Landfill 3

The geophysical surveys performed at the landfill suggest that soil or ground water contamination may be present in the upper zone. In addition, hydrogeologic investigations conducted at AF Plant 4 have revealed significant levels of contamination in the upper zone on the east side of the facility, bordering the active runway north of the landfill. Results of drilling have also shown that the Goodland/Walnut aquitard is absent at the east side of Plant 4, suggesting an increased possibility of degradation of water quality in the Paluxy aquifer. These observations are used to support the following recommendation:

- Install two upper zone monitor wells at the site. The wells should be located northwest and northeast of the inferred site boundaries, flanking the active runway. The wells should be sampled and analyzed for metals, TOC, oil and grease, phenols, and purgeable organic compounds.

Site 4, Landfill 4

Results of water quality analyses indicate that the upper zone ground water is contaminated with halogenated organic compounds east of the landfill. The degree of TCE contamination far exceeds the federal guidelines for TCE in drinking water. A variety of other halogenated compounds are present in lesser, but excessive concentrations. The downgradient limits of the contaminated ground water are not presently defined. The following recommendations are given:

- Install three upper zone monitor wells east and north of the landfill. These wells should be located on the golf course so

that at least one well monitors conditions directly north of the landfill at White Settlement road, and other wells monitor conditions at greater distances east of the landfill.

- o Perform aquifer tests (probably slug tests) on selected upper zone wells in order to determine the physical characteristics (e.g., transmissivity) of the upper zone in order to support eventual design of remedial actions.

- o Sample ground water from the Paluxy well and both proposed and existing upper zone wells. The samples should be analyzed for purgeable halocarbons (EPA Method 601).

Site 5, Landfill 5

Results of water quality analyses indicate that the upper zone ground water is contaminated with halogenated organic compounds both upgradient and downgradient of the landfill. The degree of TCE contamination far exceeds the federal guidelines for TCE in drinking water. A variety of other halogenated compounds are present in lesser, but excessive concentrations. The upgradient and downgradient limits of the contaminated ground water are not presently defined. The stream north of the landfill, as well as monitor well 5B, also shows evidence of contamination with vinyl chloride. The following recommendations are given:

- o Install five upper zone monitor wells east, west, and south of the landfill. Three wells should be located on the golf course east of the landfill in order to define water quality conditions downgradient of the site. Two wells should be installed west of the landfill in order to define hydraulic and water quality conditions closer to the taxiway. These wells should also be sited in order to investigate geologic and hydrologic

conditions in the vicinity of Landfill 7, where construction rubble has been dumped.

- o Perform aquifer tests (probably slug tests) on selected upper zone wells in order to determine the physical characteristics (e.g., transmissivity) of the upper zone in order to support eventual design of remedial actions.

- o Sample ground water from the Paluxy well and both proposed and existing upper zone wells. The samples should be analyzed for purgeable halocarbons (EPA Method 601).

Site 10, Waste Burial Area

Considering that the Waste Burial Area (Site 10) is very close to both Landfills 5 and 4 (Sites 5 and 4) and recognizing that there are few hydrogeologic distinctions between Sites 10 and 5, the recommendations offered for Landfill 5 incorporate recommendations that would be appropriate for Site 10. Furthermore, it is recommended that future distinctions between Sites 10 and 5 be ignored in favor of combining the two sites as one.

Site 11, Fire Training Area 1

Results of the Stage 1 investigation have shown that very low levels of organic compounds are present in the upper zone ground water. Federal guidelines for organic compounds in drinking water are not exceeded. Therefore, no additional wells are recommended for this site. However, the discovery of TCE in soils suggests that continued ground-water monitoring is warranted. Recommendations for further investigation are provided below:

- o Continue sampling and analysis of the two existing wells for pesticides/herbicides and purgeable organic compounds (EPA Methods 601 and 602).

Site 12, Fire Training Area 2

Results of soil and water quality analyses indicate that the upper zone is contaminated with halogenated and aromatic organic compounds. The degree of contamination, particularly in soil downgradient and at the center of the site, is significant enough (concentrations of aromatic compounds exceeding 10 ug/g) to warrant additional monitoring and analysis. In addition, levels of TCE in ground water downgradient of the site exceed the federal guidelines established for TCE in drinking water. A variety of other halogenated compounds are present in lesser, but excessive concentrations. The downgradient limits of the contaminated ground water are not presently defined. The intermittent drainage that flows to the north from the site also shows evidence of severe contamination. Accordingly, the following recommendations are given:

- Install two upper zone ground water monitor wells north and east of the site in order to determine the downgradient water quality conditions. These wells should be located in the vicinity of the intersection of White Settlement Road and Coody Drive and near the western boundary of Landfill 4.

- Conduct a series of soil borings in the vicinity of the fire training area in order to assess near-surface soil conditions. A program to sample and analyze soil vapor in the unsaturated zone in the central and north portions of the site should also be undertaken.

- Continued sampling and analysis of ground water from existing monitor wells should also be performed. The parameters for anlaysis should include purgeable organics, TOC, and oil and grease.

- Perform aquifer tests (probably slug tests) on selected upper zone wells in order to determine the physical characteristics (e.g., transmissivity) of the upper zone in order to support eventual design of remedial actions.

Site 16, Unnamed Stream

Field activities at Site 16 have documented the presence of organic contamination in upper zone ground water west of the inferred location of the french drain. In addition, elevated levels of metals and some organic compounds have also been discovered at the Unnamed Stream. These conclusions are based on a one-time sampling event; monitor wells were not installed as part of the Stage 1 actions. Therefore, the areal limits of contamination, as well as ground-water flow patterns, are not adequately known in enough detail to proceed to corrective measures design.

The following activities are recommended at the Unnamed Stream:

- A series of four upper zone monitor wells, located so as to complement the existing wells at nearby Site 15, should be installed in the vicinity of the old gasoline station and the Unnamed Stream.

- The wells should be sampled and analyzed for heavy metals, TOC, oil and grease, and purgeable organic compounds.

- Perform aquifer tests (probably slug tests) on selected upper zone wells in order to determine the physical characteristics (e.g., transmissivity) of the upper zone in order to support eventual design of remedial actions.

Site 17, POL Tank Farm

Samples of ground water collected from borings placed in the vicinity of the POL Tank Farm have shown that the upper zone is contaminated with organic compounds. Because the borings were grouted upon completion, no additional data may be obtained without continued drilling and sampling. The recommended actions for Site 17 are:

- Install five upper zone ground water monitor wells upgradient and downgradient of the POL Tank Farm in order to assess the degree of ground water contamination. They should be constructed to allow sampling of floating contaminants.

- Sample and analyze water from the wells for oil and grease, metals, and purgeable organics.

- Perform aquifer tests (probably slug tests) on selected upper zone wells in order to determine the physical characteristics (e.g., transmissivity) of the upper zone to support eventual design of remedial actions.

Site 15, Entomology Dry Well

Results of drilling and analysis of samples collected from three upper zone monitor wells do not reveal contamination at the site. However, because the dry well was not located, the degree of soil contamination, if any, in the former location of the Entomology Building is not known. The following recommendations are offered:

- A detailed search for the dry well should be conducted, and the well should be sampled. If the well cannot be located, several hand-augered soil borings should be performed in the probable location of the dry well in order to assess the impact of the well.

- Water levels at the existing upper zone monitor wells should continue to be measured in order to view the direction of ground water flow and provide ground water flow information for the investigation at Site 16.

WSA

Samples of soil collected west of the Inspection Shop contained TCE. However, no data were collected regarding shallow ground-water conditions. In addition, the potable water supply well was discovered to have an elevated level of total radium. Based on these findings, the following recommendations are made:

- Collect and reanalyze a sample from the potable water well for radionuclides.

- Install three upper zone ground water monitor wells west of the Inspection Shop. The wells should be sampled and analyzed for heavy metals, TOC, and purgeable organics.

6.2 Category III Site

Site 13, Flightline Drainage Ditch

Data gathered at the Flightline Drainage Ditch confirm that soils are affected by runoff from the flightline. Ground-water conditions directly under the site are not known, although monitor wells proposed at Site 17 would detect downgradient movement of any contamination. Otherwise the soils data are sufficient to lead to development of corrective actions.

While it is beyond the scope of the Phase II Stage 1 program to develop or design corrective measures, several conclusions can be made

regarding the type of work that could be appropriate at the site. These conclusions are presented below:

- Prior to corrective action, the ditch should be dredged and contaminated soil and sediment removed. This action will remove a possible source of future contamination.

- The main element of corrective action will probably consist of installation of a liner in the ditch, similar to the concrete-lined section already in place at the POL Tank Farm.

- The pipe that supplies fuel from the Fuel Systems Shop should be repaired. This action is currently planned by the Base Engineers.

- An oil/water separator should be considered for flow in the ditch prior to discharge into Farmers Branch.

END

1-87

DTIC